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H. L. Horning, *President* Coker F. Clarkson, *Secretary* C. B. Whittelsey, *Treasurer*

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CLEVELAND DETROIT

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XVII November, 1925 No. 5

Chronicle and Comment

The Aeronautic Meeting

ONE of the most successful Aeronautic Meetings in the Society's history was held at the Hotel Astor, New York City, on the afternoon and evening of Oct. 7. An Aeronautic Banquet attended by 325 members and guests intervened between the afternoon and evening sessions, both of which were well attended. A gratifying feature of the event was the presence of an unusually large number of persons very prominent in the field of aeronautic engineering.

A complete news-account of this meeting will be found on p. 419 of this issue of THE JOURNAL.

Events in January

DETROIT has been chosen as the scene for the next Annual Meeting and Jan. 26 to 29 as the days when the technical sessions will be held. A number of timely subjects have been proposed by the Meetings Committee and arrangements for obtaining qualified speakers are being made.

A carnival on the evening of Jan. 27 will constitute an interesting social attraction of the Meeting. Walter R. Flannery and his committee have already undertaken to formulate the plans for this event.

As previously reported, the 1926 Annual Dinner will be held at Hotel Astor, New York City, on Jan. 14. Chairman W. L. Batt, of the Dinner Committee, is arranging for suitable speakers and attractive entertainment.

The Airplane Reliability Demonstration

WITH 15 out of 17 airplanes finishing a 1900-mile intercity flight, 11 of them with perfect scores, the first commercial airplane reliability tour, the running of which was encouraged by the Society and later sanctioned, sponsored or supported, by various organizations, including the National Aeronautic Association, the Detroit Aviation Society and the Detroit Board of Commerce, was pronounced a distinct success. The practicability of air travel under severe handicaps was brought home forcefully by the splendid record made by the various entries under adverse weather conditions. An interesting collateral feature was an exposition of products of a large number of manufacturers of aviation equipment. The organizations that made this whole undertaking possible, Edsel Ford who donated the trophy for the tour, and the Ford Motor Co. which generously supported the event, deserve much thanks and credit.

The Sections Committee

A NEW Sections Committee will begin to function at the opening of the administrative year starting at the close of the Annual Meeting in January. The Society's Constitution provides that this Committee shall consist of one member of the Society to be elected from and by each Section of the Society each year prior to the Annual Meeting of the Society, and three members of the Society who shall be appointed by the President within 30 days after he takes office.

The Sections are urged to elect their respective representatives at their November meetings, if possible, and to advise the New York City office promptly with regard to their selection.

Northern California Section Inaugurated

A VERY pleasing and important advance in the work of the Society was accomplished in the inauguration on Sept. 28 of the Northern California Section, with headquarters in San Francisco. President Horning, who officiated at the establishment of the new Section, reported an auspicious beginning with every indication of a vigorous Section that will be a great credit to the Society and an inspiration to the members in the locality.

The following officers have been chosen by the Section:

Chairman, Edwin C. Wood
Vice-Chairman, Grahame B. Ridley
Treasurer, Charles W. Gebhardt
Secretary, W. S. Crowell

The officers and members of the Society extend to the Northern California Section and its officers and members hearty congratulations and best wishes for a successful career.

An account of the inauguration will be found on p. 427 of this issue of THE JOURNAL.

Production Division

THE Council at its meeting held last month took a step that it is believed will be eventually very helpful in the industry. This was the establishing of a Production Division of the Standards Committee, this action developing from discussion had since the Produc-

tion Meetings of the Society were inaugurated. At the last Production Meeting, held at Cleveland in September, specific issues were clearly raised as to the need for, the possibilities of and the ways of developing recommended practices that will lead to the reduction of needless variation in certain dimensions of machine-tools and permit interchangeability of work and tool-holding elements without the use of adapters. The feasibility of establishing standard methods for operating machine-tools of similar or identical types, but of different makes, has also been considered. In view of the interest that has been expressed by those most concerned it is hoped that good progress can be made on these and similar matters at a relatively early date.

The Institution of Automobile Engineers

SECRETARY JOY, of the Institution of Automobile Engineers of Great Britain, has reiterated the standing cordial invitation to the members of the Society to attend meetings of the Institution held in London or at automotive centers of Great Britain. The London meetings are held on the first Tuesday of each month of the season ending in May. Our members are very generously offered, while visiting London, the facilities of the Institution offices there, these including the courtesy always forthcoming from Mr. Joy. The headquarters of the Institution is Watergate House, York Buildings, Adelphi, London W. C. 2.

The Institution has issued recently a pamphlet that deserves close study by the younger, as well as the older, men who are seriously interested in automotive engineering. This is entitled The Value of the Institution to Its Graduate Members, but relates to the fundamental value and benefits that are inherent in association in a technical society. In the Institution the "Graduates" are the junior members engaged in technical studies or work. The statements contained in the pamphlet are based on essays by Graduates prepared in competition for a prize offered by Past-President Ormandy of the Institution. Excerpts from the statement are given in this issue of THE JOURNAL on p. 509. It is an excellent summary of points and principles involved in the training and development of budding automotive engineers. Obviously, the future of the industry will be measured largely by the progress of the younger men.

Farm Prosperity in America

IN a recent address Dr. David Friday, the recognized agricultural statistical authority and economist, forecast many years of prosperity in farming circles. He stated that the basis for his conclusion was the general increase in urban population and the widening markets for the products of the American farmer.

Dr. Friday anticipates a marked prosperity in the cattle industry based on the shortage of hogs this year, which will affect the markets over a period of 5 or 6 years and in turn increase the demand for beef, with far-reaching effects in the consumption of feed. The speaker predicts an increase in the demand for American farm products, inasmuch as approximately 2,000,000 more urban people must be fed each year, which is equivalent to an increase of nearly 2 per cent per annum.

Farm prosperity is the acknowledged basis of business prosperity. It is continually receiving more Federal attention and direction, with the consequent beneficial results and increased profits to the farmer. Marketing associations investigate demands and reflect prospective conditions to their members, preventing over-production, the glutting of some markets, and the under-supplying of others.

Manufacturers, after a record period of production, should plan with conservative optimism founded on continued prosperity in one of the important fundamental sources of demand for their products. During periods of prosperity in the agricultural districts an accumulated demand must be relieved that far exceeds the yearly normal need. This should be taken into account by manufacturers in planning production.

Two National Meetings in November

CORROSION in internal-combustion engines and the diagnosing of engine and car troubles will be the topics under discussion at the two sessions arranged by the Society for the Service Engineering Meeting at the Hotel La Salle, Chicago, on Nov. 9 and 10. The National Automobile Chamber of Commerce with which the Society is cooperating has arranged two other sessions on subjects of vital interest to the service-engineering fraternity. As an added attraction for those who attend the meeting, the Automotive Equipment Association has set aside Nov. 11 for our members to attend the sessions of the convention of the Association and to inspect the extensive exposition of equipment.

A discussion of automotive-transportation topics will draw a great many of the members to the Benjamin Franklin Hotel, Philadelphia, on Nov. 13 and 14, for the annual Automotive Transportation Meeting of the Society. Standardization will be the topic of the opening session on Friday morning, whereas freight-handling, store-door delivery and the use of containers will occupy the position of prominence at the afternoon session.

The committee in charge of arrangements for the Transportation Banquet that will be enjoyed on the evening of the 13th promises to offer an attraction that members will not soon forget.

Motorcoach operation will engage the attention of those who attend the morning session on Nov. 14. Following this session, the members will inspect the plant and equipment of the Philadelphia Rural Transit Co., operator of a large fleet of gasoline-electric vehicles.

Details concerning the Service-Engineering Meeting and the Automotive-Transportation Meeting are given on pp. 423-427 of this issue of THE JOURNAL. Additional information will be contained in the next *Meetings Bulletin*. Non-members of the Society will be welcome at both meetings.

STANDARDIZATION ACTIVITIES

The work of the Divisions and Subdivisions of the S. A. E. Standards Committee and other standards activities are reviewed herein

BRAKE-LINING STANDARD EXTENDED

Nine Additional Sizes Included in Proposed Revision of Present Standard

In December, 1924, a conference was called by the Division of Simplified Practice in the City of Washington on the simplification of brake-lining. At this conference the Society of Automotive Engineers was asked to submit a limited series of brake-lining sizes which would be satisfactory for new equipment and for servicing automobiles now in existence.

Using the present S.A.E. Standard as a basis, a recommendation has been developed by a Subdivision of the Parts and Fittings Division covering 25 sizes of brake-lining. These sizes in inches are:

1-1/8 x 5/32	**2-1/2 x 3/16**
1-1/4 x 5/32	3 x 3/16
1-1/2 x 5/32	1-3/4 x 1/4
1-3/4 x 5/32	**2 x 1/4**
2 x 5/32	2-1/4 x 1/4
1-1/8 x 3/16	**2-1/2 x 1/4**
1-1/4 x 3/16	**3 x 1/4**
1-1/2 x 3/16	3-1/2 x 1/4
1-5/8 x 3/16	**4 x 1/4**
1-3/4 x 3/16	**4 x 5/16**
2 x 3/16	4-1/2 x 5/16
2-1/4 x 3/16	**5 x 5/16**
6 x 5/16	

The brake-lining sizes printed in bold-face figures in the accompanying list are those that are included in the present S.A.E. Standard. The additional sizes proposed are deemed desirable for existing equipment, with the exception of the 5/16-in. sizes which are included in anticipation of motor-coach development.

An analysis of production figures for 1923 and 1924 indicates that the above sizes represent over 80 per cent of the total production and that no sizes that are not listed represent a production of over 1 per cent. The list of 25 sizes, if generally adopted in future practice, would mean the elimination of over 100 sizes. It is anticipated that this list will serve as a basis for stocking brake-lining by dealers.

The report, when approved by the Society, will be transmitted to the Division of Simplified Practice for consideration at a general conference for adoption as a recommended Simplified Practice.

SHEET-STEEL TESTS DISCUSSED

Dimensional Standardization Considered To Possess but Little Value

At a meeting of the Subdivision on Sheet Steel held in Cleveland on Nov. 15, W. C. Peterson, chairman of the Subdivision, stated that a recent investigation of the extent to which sheet steel is tested by users shows that tests are seldom made. Reliance is placed entirely on the use of proper forming dies and machines for working the sheet steel.

J. M. Darke stated that the Sheet Steel Subcommittee of the American Society for Testing Materials had prepared specifications for cold-rolled strip which include chemical composition, but that this material is different from sheet metal as it is usually used when high strength in the product is wanted. He also said that the chemical composition is important especially with regard to carbon and that it is relatively easy to control the physical properties for each grade. He added that the American Society for Testing Materials has a specification for a galvanized sheet that is relatively easy to handle in the forming processes, but that the specification has been used very little since it was issued about a year ago.

Representatives of the sheet steel manufacturers were of the opinion that dimensional standardization, including the sheet thickness, would be of little use in manufacture because it is now a simple matter to meet customers' requirements. Moreover the requirements of the industry are always changing.

The Subdivision finally decided that before discontinuing work on this subject, a final questionnaire should be sent to the larger users of sheet steel to determine present conditions and requirements. The information obtained will be used as a basis for the final report of the Subdivision.

Those present at the Subdivision meeting were W. C. Peterson, of the Fredericksen Co., chairman; J. M. Darke, of the General Electric Co.; W. A. Irvin, of the American Sheet & Tin Plate Co.; R. F. Kenyon, of the American Rolling Mill Co.; W. G. Tamplin and Robert H. Dibble, of the American Sheet & Tin Plate Co.; J. M. Watson, of the Hupp Motor Car Corporation; and Standards Department Manager R. S. Burnett.

NEW BALL-BEARING NUMBERS PROPOSED

Changes in Width of Light Series of Wide-Type Bearings Adopted by Division

In the present S.A.E. Standards for Ball Bearings, the 200, 300 and 400 series are used to designate the single-row and the double-row radial and the angular-contact types of ball bearing. In order that there might be a standard system of designating ball-bearing types which would permit absolute identification by the S.A.E. bearing number, the Ball and Roller Bearings Division appointed a Subdivision consisting of E. R. Carter, Jr., L. A. Cummings and T. C. Delaval-Crow to review the present numbering system and to recommend proper changes. The Subdivision, as a result of a meeting in New Britain on Sept. 30, drew up a report which was submitted to the Division at the meeting on Oct. 16 in New York City. The following is quoted from the Subdivision report:

> The proposed numbering system leaves the use of letter suffixes for the individual manufacturer to indicate variations and modifications from standard types. For instance, a No. 205 bearing in the type using the maximum number of balls might be styled by one manufacturer as a No. 205-M and in the Conrad construction as a No. 205-C. Nevertheless, the bearing itself is the No. 205 standard size, as indicated by the number, positively identifying it as such according to the S.A.E. Standard dimensions. In other words, the internal construction, as developed by the individual manufacturer, need not have any influence on the standardized dimensions or the standardized designation.
>
> The Subdivision's recommendation is submitted to clarify a situation that is becoming more and more complicated and confusing as time goes on. The adoption of the proposed designations rests entirely with the individual ball-bearing manufacturers, to be em-

ployed only when and if each individual manufacturer sees fit. It does, however, give a standard system of designating types from the engineering and the user's standpoint. Moreover, it properly classifies and designates any type that a manufacturer may produce in the future which is at the present time unknown to his manufacturing schedules.

As a result of a general discussion of the report, the Division revised the recommendation by the adoption of the 7000 series for the angular-contact type instead of the 0000 series and eliminated the first two digits in the bearing numbers for the extra-small series. The ball-bearing series together with the present and the proposed numbers are listed below.

Type	Present Series	Proposed Series
Separable (Open) Type	5 to 19	5 to19
Extra-Small Series	9430 to 9435	30 to 35
Radial, Light Series	200	200
Radial, Medium Series	300	300
Radial, Heavy Series	400	400
Wide-Type, Light Series	200	5200
Wide-Type, Medium Series	300	5300
Wide-Type, Heavy Series	400	5400
Angular-Contact Type, Light Series	200	7200
Angular-Contact Type, Medium Series	300	7300
Angular-Contact Type, Heavy Series	400	7400

The proposal made by F. G. Hughes, of the New Departure Mfg. Co., suggesting certain changes in the widths of the wide-ball type ball bearing standard was considered feasible and the Division voted to recommend the changes, which are given below, for adoption at the next meeting of the Standards Committee.

WIDE-TYPE ANNULAR BALL-BEARINGS

Bearing No.	Present Width, In.	Proposed Width, In.
206	3/4	15/16
207	7/8	1-1/16
208	1	1-3/16
209	1	1-3/16
210	1	1-3/16
211	1-3/16	1-5/16
212	1-3/8	1-7/16
213	1-3/8	1-1/2
214	1-7/16	1-9/16
215	1-7/16	1-5/8
216	1-5/8	1-3/4
217	1-3/4	1-15/16
218	2	2-1/16
219	2-3/16	No change
220	2-3/8	No change
221	2-9/16	No change
222	2-3/4	No change

Those present at the meeting were F. W. Gurney and John H. Baninger, of the Gurney Division of the Marlin-Rockwell Corporation; H. E. Brunner, of S. K. F. Industries, Inc.; D. F. Chambers, of the Bearings Co. of America; L. A. Cummings, of the Standard Steel & Bearings, Inc.; T. C. Delaval-Crow, of the New Departure Mfg. Co.; H. N. Parsons, of the Strom Division of the Marlin-Rockwell Corporation; and R. S. Burnett and C. E. Heywood, of the Standards Department.

STANDARD INSERTS NOT USED

Survey Indicates That 11 Threads Are Used for Control-Lever Ball-Handles

The S.A.E. Standard for Control-Lever Ball-Handle Inserts was drawn up by the Transmission Division and approved by the Society in 1920. Information submitted some time ago indicated that this standard had never been adopted by the industry and a survey was therefore made.

The summary indicates that 11 threads are used by the various car-builders and that only 5 out of 36 companies are using the thread published by the Society as "Standard." The threads used, together with the number of car builders using the threads, are as follows:

Thread	Number of Users
1/8 Pipe	1
1/4 Pipe	4
5/16-24	1
3/8-16	2
3/8-24	11
7/16-18	1
7/16-20	2
1/2-13	4
1/2-20 (S.A.E. Standard)	5
1/2-20 External	1
5/8-18	4
	36

As a result of this survey the Transmission Division is to review current practice and draw up a revised standard which, it is hoped, will meet the various requirements of the industry from the viewpoints of cost and serviceability.

HOLDING POWER OF WOOD SCREWS

Bureau of Standards Tests Holding Power of Screws in Seven Kinds of Wood

Although the automotive industry has depended on the holding power of the wood-screws for many important structural parts, little real information has ever been compiled showing the actual holding power of wood-screws for various conditions such as the kind of wood, the size of the lead hole and the lubricant used. The industry will, therefore, be interested in knowing that the Bureau of Standards has recently conducted tests of over 10,000 wood-screws of various sizes, using yellow poplar, cypress, sycamore, Georgia pine, North Carolina pine, hard maple and white oak. The effect of various factors on the holding power such as the use of a lead hole and of a lubricant, is also being studied. It is believed that accurate data, the first of their kind on this important subject, will be secured as a result of this work.

STANDARDS CLASSIFIED AND DEFINED

F. J. Schlink Describes the Various Kinds Used in Engineering and Industry

The following abstract of a paper entitled Classification of Engineering and Industrial Standards written by F. J. Schlink, assistant secretary of the American Engineering Standards Committee, will be found of interest to those who have followed the standardization work of the industry. The paper was printed in full in *Mechanical Engineering*, but in the following abstract the definitions of the various kinds of standards are given in full, the deletions having been limited largely to explanatory examples.

CLASSIFICATION OF STANDARDS

Industrial standardization is the setting up, publication, and use of units, constructional forms, designs, manufacturing methods, processes, or routines which are determined upon by engineering study and analysis as being best and most economical for their respective purposes, in place of diverse ones of varying or indefinite character and quality. By this planned uniformity of operation, process, or product, standardization brings about economy in material, labor and administration.

Standards are of several kinds

(1) Fundamental units and standards of length, mass, time and temperature
(2) Nomenclature
(3) Dimensional standards
(4) Standard ratings

(5) Standards of quality
(6) Standards of practice

The most fundamental type of standards is the basic weight and measure standards of the Country, such as the standard yard and pound, the volt, the candlepower and the like, as defined by legal or other authority, and referred to fundamental or prototype standards carefully maintained in the vaults and laboratories of the Bureau of Standards at the City of Washington. These are not ordinarily considered as within the scope of industrial standardization, but they are of first importance in any standardization program.

The determination and definition of these standards in such form that they can be reliably used and reproduced when needed, represent an enormous amount of work, of incalculable importance to industry, inasmuch as they permit the reproduction of standardized dimensions without the necessity of building and maintaining an actual model or sample.

Nomenclature, or standards which define terms, or establish nomenclature or standard symbols include

(1) Standard terms and their definitions
(2) Symbols
    (*a*) Algebraic—for use in formulas
    (*b*) Graphic—ideographs or pictographs
    (*c*) Abbreviations

Standards of Size and Form—Dimensional Standards, or those which establish particular dimensions, or combinations of dimensions, for the construction or working of machines and equipment or their components. The dimensions standardized are usually chosen as

(1) Suiting to the best degree the requirements of existing buildings, equipment, apparatus, machines, tools, or parts, by providing for intermembering or interworking, or interchangeability of parts and supplies
    (*a*) A more highly developed form of this type of standard is seen in what may be called the standard component, a specialized machine part or device which may be used in more than one assembly. This type of standardization is particularly common in communication and other electrical industries where a single small standard part may appear in numerous and very diverse assemblies
(2) Combining in a single instrument, device or practice, needed characteristics of suitability, convenience, capacity, economy and strength for a given purpose or a group of purposes having common factors. The needed characteristics are expressed in terms of physical and chemical properties, such as mechanical, electrical, optical, chemical and other definable characteristics

Standard Ratings, or those which establish a limit of use or operation within which certain requirements, as to performance, durability, reliability, safety and the like, must be met.

Standards of Quality or specifications setting up standards of purity, strength, elasticity, durability, color, workmanship and other non-dimensional characteristics which determine the industrial or engineering usefulness or appearance of raw or intermediate materials, semi-finished products or of structures, equipment or machines. This is the class often loosely known as purchase specifications.

Standards of Practice includes the establishment of the practice or process best suited to the purpose in hand, to insure the most rapid, most accurate, cheapest or otherwise most advantageous method of carrying on an operation or process or operating a machine or device. In some cases these are called construction specifications. In others they may be drafted primarily from the point of view of safety to workers, in which case they fall into the class of safety codes.

Methods of Test are to be classed as process or operation specifications, being standards of practice applicable to the determination of the degree of conformity of apparatus, components, or materials to quality or dimensional standards or ratings. Methods of test are not, therefore, independent standards of practice, but are to be considered as auxiliary to the setting-up and practical use of other standards. Methods of test in turn are sometimes known under two classes, for (*a*) quick, ready, routine use and (*b*) precise work, required perhaps in settling controversial cases.

Safety Codes are not a distinct class of standards, but partake of the characteristics of several of the foregoing, as is suggested under Standards of Practice.

Scope of Standardization and Simplification

Simplification, as the term is used by the division of simplified practice of the Department of Commerce, is an elementary or preliminary form of standardization, and may be applied to a number of the above fields by elimination of unnecessary variety of types, forms, sizes, ranges, capacities, qualities, and the like of materials or manufactured products. Simplification is distinguished by the fact that it does not set-up new items, but selects, usually on commercial grounds, from a series of items already in existence or on the market. In the practice of the Division of Simplified Practice, the selection is based upon relative consumer demand for the several sizes and varieties entering into production and distribution.

Standardization, on the other hand, may, on occasion, supplant all existing items or practices by new ones, usually fewer in number, where circumstances require such modification of existing practice, or in new fields of development may even set-up a standard in advance of practice.

Classification of Standards by Use

Standards may be classed on the basis of their degree of acceptance: those in regular customary use being known as "standards," while those in an initial or trial stage are known as "tentative" or "provisional standards." In ordinary course it is assumed that such standards will advance to the status of regular standards.

A further classification of standards is possible with respect to the time and trend of their utilization, thus

Obsolete
Obsolescent
Standard
Prospective Standard
Ad Interim Standard

The last is intended to bridge an interval between an obsolescent and a current standard, or between a standard and a prospective standard.

In an actively growing and developing industry, all of these classes of standards are often involved. Some may be designated as definitely obsolete and others are to become obsolete after the lapse of a certain interval or upon exhaustion of existing stock. The third class of active standards is that for which no change of application is as yet foreseen, while future or prospective standards may be established for utilization after a certain period of time or upon the completion of certain preparatory stages, or of related standardization work in other fields.

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

RESEARCH TO DETERMINE FUEL NEEDS

Desirable Difference in Volatility in Winter and Summer To Be Studied

The Bureau of Mines has just issued its twelfth semi-annual motor-gasoline survey, bringing up to date its history of gasoline marketed throughout the United States. In the accompanying chart are given the average distillation-points found from the surveys made up to January, 1925. It includes the three investigations made in April, 1915, 1917 and 1919, prior to the initiation of the regular semi-annual researches. Inasmuch as the figures for July, 1925, were not ready when the chart was drawn, they are given as follows: Initial boiling-point, 108 deg. fahr.; 20-per cent point, 204 deg. fahr.; 50-per cent, 275 deg. fahr.; 90-per cent, 387 deg. fahr.; and end-point, 427 deg. fahr.

Members of the Society will find the chart of particular interest because of its bearing on two new projects under consideration. These projects, authorized at the last meeting of the Steering Committee for the Cooperative Fuel-Research are (*a*) an investigation of the seasonal distribution of fuels to determine what differences in volatility are essential for the obtaining of approximately the same performance in winter as in summer as regards starting, flexibility and general engine operation; and (*b*) an economic motor-fuel survey to determine the most suitable fuel for the motor vehicles now in use. In proposing the first investigation, emphasis was placed on the increasing use of motor vehicles in the winter, due to the improvement in highways, and to the lower prices of closed cars. In discussing the second, the proviso was made that the tests shall be carried on with current models, so that the information obtained will be applicable 2 years hence. Both of the projects are stimulated by the desire of the Society to cooperate with other organizations to bring about the most economic use of our petroleum fuels. In both of these researches, the Society expects that the Bureau of Standards, the American Petroleum Institute and the National Automobile Chamber of Commerce will participate.

While these researches are intended to give information on the qualities desired, the Bureau of Mines report presents information on the quality of gasoline as it is actually sold throughout the United States. For making these surveys, samples, about 150 in number, are collected from filling-stations and garages in the cities of New York; Washington; Pittsburgh; Chicago; New Orleans; St. Louis; Bartlesville, Okla.; Denver; Laramie, Wyo.; and San Francisco. It is thought that conditions in these cities are representative of those existing throughout the major marketing territories, and therefore that the samples indicate truly the gasoline available to consumers in the United States. Since the collections were made in January and July, the contrast between the winter and summer fuels is clearly drawn. The methods of testing are the same as those used by the Federal Specifications Board for liquid fuels.

Changes in Quality Since 1915

Much discussion has been had of the general change in the quality of gasoline since 1915. The chart shows that the fluctuations which have taken place from year to year have followed no regular course; that gasoline has not grown steadily more volatile, or less volatile. At just what point the fluctuations should stop to serve the best interest of the motor-car user should be determined by the second of the proposed joint projects mentioned above, namely, the economic motor-fuel survey. Of greater present interest, now that the cold weather has set in, is the contrast between summer and winter fuels. Table 1 gives the increase or decrease in degrees fahrenheit at the five distillation-points based on the immediately preceding Bureau of Mines investigation. For example, the first column gives the differences between the January and July, 1920, figures; the second, between the July, 1920, and the January, 1921, figures; and so on. Wherever the variation was opposite to that which was to be expected, that is, where the temperature at the distillation-point is lower for July than for January of the same year, or higher for January than for the preceding July, the figure is set in bold-face type.

TABLE 1—VARIATION IN THE DISTILLATION POINTS OF GASOLINE

	Initial Boiling-Point, Deg. Fahr.	20 Per Cent, Deg. Fahr.	50 Per Cent, Deg. Fahr.	90 Per Cent, Deg. Fahr.	End-Point, Deg. Fahr.
July, 1920	+11	+ 8	+ 9	+19	+19
January, 1921	—17	—11	— 7	—11	—15
July, 1921	+12	+ 5	+ 1	0	+ 2
January, 1922	—23	— 2	+ 5	0	— 3
July, 1922	+19	+ 8	+ 3	— 2	— 1
January, 1923	—14	— 7	— 3	0	— 2
July, 1923	+18	+ 5	+ 2	+ 7	+ 9
January, 1924	—29	—10	— 2	+ 1	— 5
July, 1924	+11	+ 4	+ 4	+ 7	0
January, 1925	—12	— 5	— 5	— 8	— 6
July, 1925	+13	+ 9	+ 9	+ 5	+ 2

It must be borne in mind that the initial boiling-point is not considered a criterion of the suitability of a fuel for a motor vehicle. A fuel may pass the "first-drop" test and still contain a sufficient quantity of low-volatile constituents to cause difficulty in starting. For similar reasons the end-point is not thought to be of much value. However, it is generally recognized that the 20-per cent and 90-per cent points constitute a basis for a fair judgment of gasoline. So widely accepted is this fact that the technical committee on lubricants and liquid fuels of the Federal Specifications Board has made a tentative change in the specification for United States Government motor-gasoline, the principal object being the elimination of the specifying of the initial boiling-point and the end-point. Should experimental use of the modified specification prove its utility, the committee will discuss the feasibility of making the tentative change permanent.

Study of the Variations in Volatility

A study of the table will show that the fluctuations between winter and summer gasoline, with the exception of those pertaining to the initial boiling-point, are small. Roughly speaking, the changes decreased in importance until 1924. In that year the 20, the 50 and the 90-per cent distillation-points of the average motor-fuels sold were only between 4 and 7 deg. fahr. higher in July than in January. The seasonal fluctuations since July, 1924, have been somewhat more marked.

That changes in gasoline volatility are not made strictly in accordance with the seasonal fuel requirements of motor vehicles may be observed from the figures given on the chart for January, 1923, and July, 1924. The average fuels for both these periods had the same initial boiling-points, the

20-per cent points differing by only 1 deg. and 50-per cent points and end-points being 4 deg. apart. The only decided difference, 15 deg., was found at the 90-per cent point.

Just what factors bring about these changes? For an analysis of possible causes, the fourth semi-annual motor-gasoline survey may be consulted. In spite of a drop in price, the gasoline sold in July, 1921, was much better than that sold in July, 1920, and was almost identical with the average gasoline available to the consumer in January, 1921. The reason for this was excessive production.

Individual Figures Give Truer Picture

If the analysis could be carried further to secure the figures for the individual cities, instead of general averages, a truer picture could be gained of the differences in gasoline quality. Decided difference is seen to exist between fuels sold at the same time in the cities in which samples were collected. For instance, in July, 1925, the initial boiling-point ranged from 100 deg. fahr. for samples collected in Bartlesville, Okla., to 121 for the City of Washington fuels; the 20-per cent point, from 192 in Pittsburgh to 212 in Chicago and New York City; the 50-per cent point, from 254 in Pittsburgh to 287 in Bartlesville, Okla.; and the 90-per cent point, from 378 in San Francisco to 400 in Bartlesville, Okla.; while the lowest and highest end-points were 415, in Laramie, Wyo., and 435, in Bartlesville, Okla.

Also, gasolines sold in a given city in summer vary widely from year to year. The figures given in Table 2 illustrate this condition for Chicago.

TABLE 2—VARIATION IN THE QUALITY OF GASOLINE SOLD AT CHICAGO IN TWO YEARS

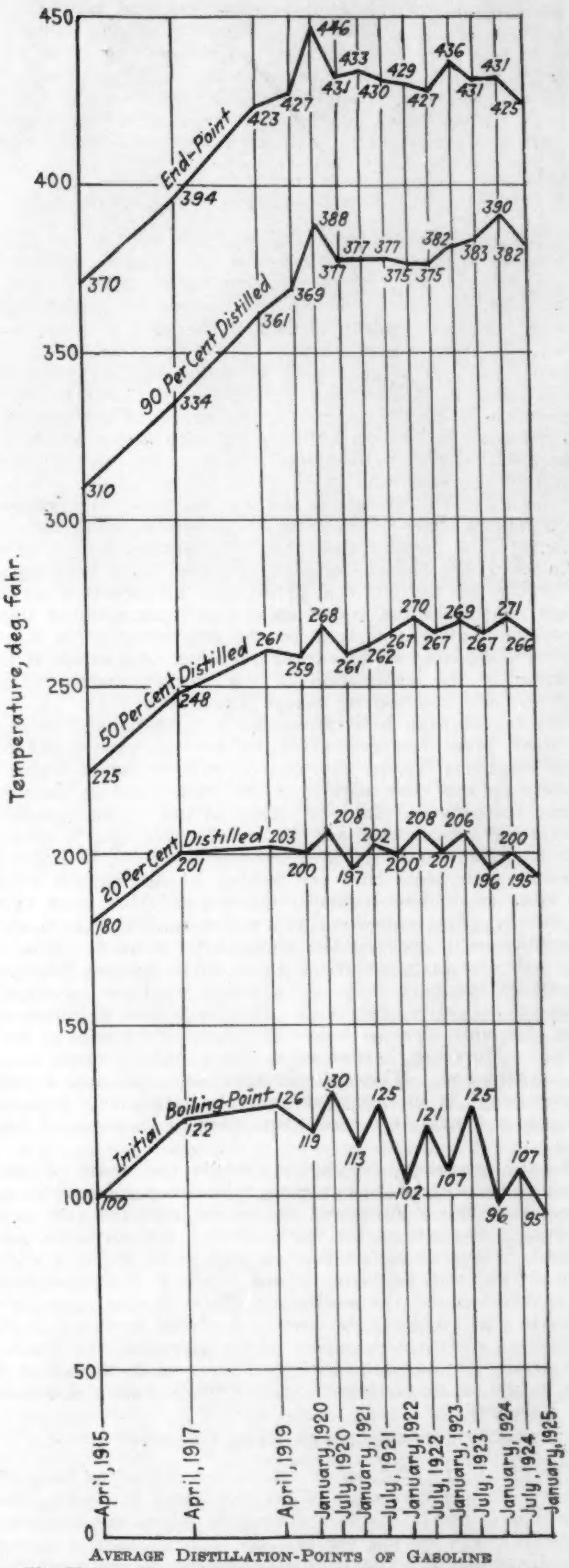
	July, 1924	July, 1925
Initial Boiling-Point, deg. fahr.	100	111
20 Per Cent Distilled, deg. fahr.	200	212
50 Per Cent Distilled, deg. fahr.	278	285
90 Per Cent Distilled, deg. fahr.	398	404
End-Point, deg. fahr.	433	439

Likewise, fuels sold in the same city at different seasons are sometimes almost identical in quality. As an example, Table 3 gives the figures for New York City.

TABLE 3—QUALITY OF GASOLINE SOLD AT NEW YORK CITY IN 1924

	January, 1924	July, 1924
Initial Boiling-Point, deg. fahr.	97	105
20 Per Cent Distilled, deg. fahr.	204	203
50 Per Cent Distilled, deg. fahr.	275	275
90 Per Cent Distilled, deg. fahr.	385	385
End-Point, deg. fahr.	427	427

Even this cursory examination of the gasoline surveys indicates that a definite criterion of winter and summer fuel needs is required. Not only do the volatility fluctuations, as shown in the general averages, vary from year to year, but they sometimes disappear entirely. Conditions other than engine requirements, such as over-production, are found to have a predominant influence on the volatility of the fuels supplied to consumers. Study of figures for individual cities would undoubtedly show even more clearly a wide variation from the ideal condition. The Cooperative Fuel-Research, by establishing a standard of desirable difference in volatility between summer and winter fuel, should assist materially in reaching the goal of economic fuel-utilization.



AVERAGE DISTILLATION-POINTS OF GASOLINE

The Values Given for the Initial Boiling: 20, 50 and 90-Per Cent; and the End-Points Were Those Obtained by the Bureau of Mines in Its Motor Gasoline Surveys of April, 1915, 1917 and 1919 and the Semi-Annual Surveys Made in January and July of Each Year Since 1920. The Results of the July, 1925, Survey Were Not Available When This Chart Was Made Up and Are As Follows: Initial Boiling-Point, 108 Deg. Fahr.; 20 Per Cent Distilled, 204 Deg. Fahr.; 50 Per Cent Distilled, 275 Deg. Fahr.; 90 Per Cent Distilled, 387 Deg. Fahr.; and End-Point, 427 Deg. Fahr.

EFFICIENCY AND DURABILITY OF GEARS

Wear and Breakdown Tests of Greater Importance Than Stress Calculations

The gear-production session at the Society's Production Meeting in Cleveland was not only of great interest to production engineers but to designers as well. Past-President Alden, chairman of the session, emphasized the point that the mathematical basis for the design of gears can be much

improved; in fact, he let it be known that his company would soon be able to give out some very interesting results pertaining to gear design. This intimation of progress is very timely because it is realized that the art of gear production has advanced more rapidly than the knowledge of the kinematic principles of gearing. Gears that served a purpose years ago are not acceptable at present and those produced at present may not be satisfactory for the future.

Strength Determinations and Calculations

It is universally agreed that strength calculations of gears such as are used in motor vehicles are not complete if merely checked with the formulas that are based on the assumption that teeth are cantilevers loaded at the end, considering, of course, the pitch, width of face of the gear and the number of teeth. The reason for this can be found in the fact that abrupt failures of gear teeth in motor-car transmissions or rear axles are not common and if they do occur are usually traceable to poor material, improper heat-treatment, flaws in the gears or foreign particles jamming themselves between the teeth, rather than to fiber stresses exceeding the elastic-limit of the material.

One kind of tooth failure that can be noted very frequently is a flaking-away of material or an erosion near the pitch-line. It has been realized that this kind of failure is very similar to that encountered in ball and roller bearings and that it is due to high local pressures. To predetermine these high local pressures, wider use is now being made of Hertz's equation that was derived for the determination of stresses in the contact areas of curved surfaces. An excellent illustration of the application of the Hertz equation to gear calculations is given by Joseph Jandasek[1].

To reduce high local pressures it is customary to choose a small pressure-angle which reduces the separating force and lengthens the arc of contact. A long arc of contact of course assures that more than one tooth shall be simultaneously in contact. However, teeth having a small pressure-angle are slender and lack the rigidity that can be obtained by resorting to large pressure-angles. This is important because gear teeth that are lacking in rigidity are subject to vibration and consequently noisier, and they wear faster.

Another very interesting method for determining the stress distribution in gears is the photoelastic method. With this method, circularly polarized light when passed through a model of the part to be investigated produces color bands that are indicative of stresses. The limitations of this method are that only stresses below the elastic-limit can be determined. Moreover, hardening or other initial stresses cannot be determined. These limitations are not objectionable. However, it is inconvenient that the stress determinations have to be made on a model composed of transparent material.

In the gearboxes for motor vehicles the width of gears must be reduced to the minimum to obtain a compact design. Because of this requirement the tendency on the part of designers is to overload the teeth, causing extraordinary pressures. Designers should bear in mind that there is a definite critical unit-pressure beyond which it is advisable not to go if we want the working surfaces of the gears to be durable. In addition, the hardness of the surfaces in contact, the quantity and quality of the lubricant, the finish of the gear teeth, and the rigidity of the gear teeth and of the shafts have to be given very serious consideration if durability is desired.

Efficiency of Spur Gearing

The durability of gears is intimately related to their efficiency. The determination of friction losses in gearing have been elusive and it has been difficult to repeat any tests with precision. The reason for this no doubt is that it is very difficult to separate the friction losses due to the tooth contacts from those due to the bearings. However, from a large number of tests one fact has become well known, namely, that the efficiency varies with the ratio. For instance, a reduction of 2 to 1 will be more efficient than a reduction of 10 to 1. Attempts have been made to calculate the efficiency of gearing, using the sliding of the teeth relative to each other as a basis. But the results have never been gratifying. The reason for this can be found in some very reliable test-results on the efficiency of spur gearing published by the University of Illinois. In these the efficiency for well-cut gears has been found to be better than 99 per cent over a considerable range of loads and speeds. It is evident that no formula based on relative sliding and a coefficient of friction would give results that are accurate within 1 per cent. The tests[2] referred to have been reported by Prof. C. W. Ham and J. W. Huckert whose object was to conduct tests on a machine designed by Wilfred Lewis and to secure reliable information on the efficiency of spur gearing and on the wear, or more accurately on the change and the rate of change in the profiles, of spur-gear teeth in use. Their deductions from the tests are of great interest to automotive engineers and for this reason they are quoted below.

Summary of Conclusions on Efficiency, Considering Tooth Friction Only

(1) The efficiency of unhardened gears is practically independent of the quantity of oil used for lubrication provided the quantity is sufficient to prevent heating and cutting

(2) The efficiency is independent of the speed within the range covered by this investigation, namely, a pitch-line speed of 60 to 1500 ft. per min.

(3) The efficiency does not appear to be influenced by the obliquity action

(4) For all practical purposes the efficiency is independent of the load transmitted. The value of 99 per cent is suggested for use in computations dealing with the efficiency of gears cut in accordance with good commercial practice

(5) Condition of tooth surface is the most important of the factors that affect the efficiency of unhardened gears. Gears with rough tooth-surfaces are less efficient than those in which the tooth-surfaces have become glazed, but the difference in efficiency is not as great as has been commonly assumed

(6) When all other conditions are the same, greater sliding action causes the longer-addendum gears to have a slightly lower efficiency than the shorter-addendum gears. On the other hand, the vibration of the longer-addendum gears may, for certain ratios, be so much less than that of the shorter-addendum gears as to result in a slightly higher efficiency of the longer-addendum gears

(7) The difference in efficiency of the several standard tooth-forms in common use is so small as to exercise no controlling influence on the tooth-form to be recommended or adopted for any purpose.

Summary of Conclusions on Durability

(1) Unhardened steel pinion teeth quickly wear to outlines other than true involutes, regardless of load, speed and lubrication; after this occurs wear practically ceases or is greatly retarded under ordinary conditions

(2) The teeth of cast-iron gears meshing with steel pinions fail by crushing of the material in the region of the pitch-line

(3) The teeth of unhardened steel pinions meshing with cast-iron gears fail by abrasive action that wears off the face of the tooth and hollows out the flank, resulting, in general, in a final outline of double curvature

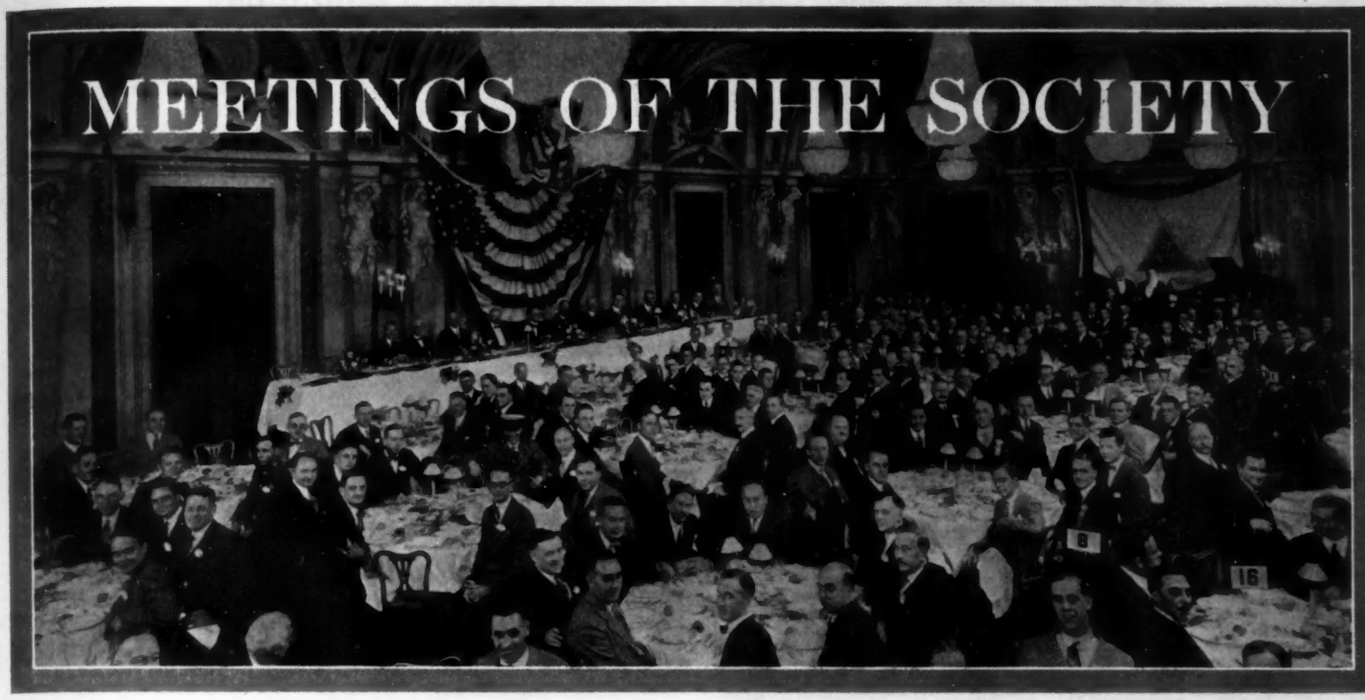
(4) Lubrication is a very important factor in the life of unhardened gears. Although the quantity of lubricant does not materially affect the final change in tooth outline due to wear, it postpones the beginning of the rapid wear of both pinion and gear and thus greatly prolongs the life of the gears

(5) Under the same conditions of load, speed and lu-

(*Concluded on p.* 451)

[1] See *Automotive Industries*, July 10, 1920, p. 1305.

[2] See University of Illinois Engineering Experiment Station Bulletin No. 149.



ATTENDANCE AT AERONAUTIC MEETING 300

Two Sessions on Design, Construction and Operation, with Banquet Intervening

Some 300 members and guests of the Society responded to the invitation to attend the technical sessions and banquet of the Aeronautic Meeting at the Hotel Astor, New York City, on Oct. 7. Among those present were many personages of great prominence in both military and commercial aeronautic circles.

Papers presented at the afternoon session, prepared by H. M. Crane, W. L. LePage, G. J. Mead and W. L. Gilmore, dealt with design and construction topics, whereas the addresses at the evening session, prepared by W. B. Stout, J. E. Whitbeck and J. P. Van Zandt, dealt with operation problems. Grover Loening and Paul Henderson presided respectively at the afternoon and evening sessions.

At the banquet that followed the afternoon session, the Society was honored by the presence of many distinguished engineers and patrons of aviation, including a number of foreign guests. Clement M. Keys, president of the Curtiss Aeroplane & Motor Co., in his address raised a number of important points of special interest at this time. Past-President Crane functioned in the capacity of toastmaster.

For suggestions leading to the successful arrangement of the annual Aeronautic Meeting, an event of national importance in the Society's calendar, the Society is obligated especially to P. G. Zimmermann, second vice-president, for aeronautic engineering, and to E. P. Warner. A detailed account of the meeting and banquet will be found below.

AIRPLANE DESIGN AND CONSTRUCTION

Afternoon Session Is Devoted to Four Papers by Well-Known Authorities

Aeronautic development and progress from the standpoints of design and construction held the attention of about 200 members of the Society and their guests during the opening session of the Aeronautic Meeting of the Society held at the Hotel Astor, New York City, on Wednesday afternoon, Oct. 7.

Four papers by well-known authorities were devoted to the different phases of the subject. First, H. M. Crane explained the object of, the methods employed in preparing, and the meaning of the Aeronautic Safety Code, which has just been completed after 5 years' work by a sectional committee sponsored by the Bureau of Standards and the Society. W. L. Gilmore's paper on the Evolution of the Racing Airplane was read by C. M. Keys, president of the Curtiss Aeroplane & Motor Co., in the absence of the author, who is chief engineer of the same company. Some Aspects of Aircraft Engine Development was presented by G. J. Mead, of the Pratt & Whitney Aircraft Co., and the Light Airplane and Low-Powered Flying was discussed by W. L. LePage, editor of *Aviation*.

The Aeronautic Safety Code

Most industries, said Mr. Crane, complain because they get too much control. The aviation industry is the only one that has spent a large part of its time in the City of Washington "yelling" for control. It will get control, he said, and it is to its advantage that it gets the proper kind.

The Aeronautic Safety Code, Mr. Crane explained, is the outgrowth of an increased activity in standardization of a National character on the part of the American Engineering Standards Committee soon after the war. This Committee does not attempt to standardize but coordinates the efforts of other bodies attempting to standardize. It operates through a sectional committee under the control of one or more sponsor bodies. The sponsors act as a steering committee. They do not control the sectional committee in any sense, but pass on the membership of the sectional committee and have a final power of veto or acceptance after the work of the sectional committee has been completed.

Following a preliminary conference in the City of Washington on May 13, 1921, a meeting for organization was held on Sept. 22 of the same year. Six subsequent meetings of the main committee have been held to pass on the work of the subcommittees, which in turn have held between 30 and 40 meetings, covering the 10 different parts of the Code.

The personnel of the main and the subcommittees, said Mr. Crane, is practically a roster of the aeronautic industry in this Country and the ideas expressed by every member have been given full consideration. Although the Code has been in course of preparation for 5 years, it is open to the objection of not having been tried, and of not being the product of actual experience and use. But the only way to try it is to put it into actual service and see what happens. The underlying idea in its formulation has been that it shall serve as a basis upon which control of aviation in this Country can be exercised, when such control shall have been placed under the jurisdiction of the Department of Commerce, as is likely to be the case.

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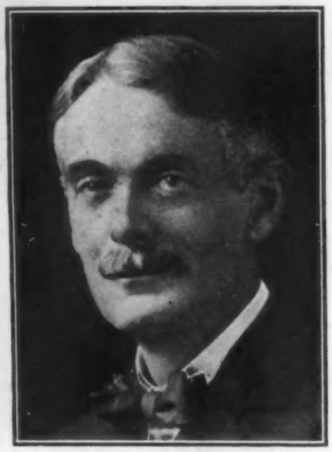
GROVER C. LOENING



HENRY M. CRANE

The present status of the Code, added Mr. Crane, is as follows. It was accepted by the Society through its Standards Committee at the 1925 Summer Meeting at White Sulphur Springs, W. Va., was subsequently accepted by the Council of the Society and submitted to a mail vote of the members of the Society, received a favorable vote from them, has been accepted by the Bureau of Standards, and will next go before the American Engineering Standards Committee for final action. After acceptance, by the last named, the Code, under the procedure, will become a tentative American standard subject to change at any time by action of the sponsor bodies through the sectional committee, which will remain in existence.

How the Modern Racing Airplane Developed

Unless he has dabbled somewhat in design himself, said Mr. Gilmore in discussing the Evolution of the Modern Racing Airplane, a person, although he may marvel at the enormous advance in design that has taken place in the last few years, can hardly be familiar with the enormous amount of time, effort and ingenuity that have been expended to make super-speed airplanes possible. He then outlined the method of procedure adopted in producing a specific model and the yearly progress that has been made uptodate.

Following in detail the steps taken in allocating the work to the various departments, Mr. Gilmore described the evolution of the several types of airplane and the consideration given to such subjects as thickness of wing-section, strength, rigidity, weight, lift, drag, wing and tail areas, and the like.

Having obtained a fairly definite idea of the overall dimensions of the airplane, he said, a drawing is made for a wind-tunnel model, which is carved by hand from seasoned mahogany and is an exact duplicate of the large airplane, except that it is only one-twelfth its size. This model serves the threefold purpose of giving the designer a true picture of the completed airplane, of checking the high speed of the machine in the wind-tunnel, and of determining its controllability and stability.

GEORGE J. MEAD

W. LAURENCE LE PAGE

Interesting details were given of the reasons for deciding upon the present methods of constructing the wings, tail surfaces, landing-gear, fuselage, powerplant, propellers, radiators and control system. After the first product under a contract has been completed, it is carefully tested statically by sand-loading to make sure that no defects exist. These tests simulate high speed, low speed, inverted flight, two-point landing with a side wind and tail-skid landing. The control surfaces and control systems are also tested under load. Mr. Gilmore's paper is printed in full on p. 476 of this issue of THE JOURNAL.

Various Aspects of Engine Development

Having passed through the experimental and demonstration stages of development, airplanes must ensure infallible performance and economical operation in order that flying may be placed upon a commercial and paying basis, said Mr. Mead in presenting Some Aspects of Aircraft-Engine Development. Purely military requirements have fostered the use of power rather than refinement to obtain performance, but satisfactory commercial operation demands all-round efficiency of the powerplant; and improvement is still possible in the four essentials, dependability, size, total powerplant weight and cost.

Dependability, according to Mr. Mead, involves experience in design, intelligent engine-rating, conscientious manufacturing and proper service-care. The use of power alone to secure performance is uneconomical. It is as useless to over-power an airplane as a tow-boat; for every airplane a certain size of engine is most economical, and it depends upon the drag of the airplane, the performance required, the propeller efficiency and the efficiency of the engine. At present, available power-units are separated by approximately 100 hp., making it relatively easy to secure the correct size for any given service.

It is important to consider the total weight of the powerplant for any given service, including the weight of the fuel and oil, continued Mr. Mead. Sometimes a slightly heavier engine will have a lower fuel-consumption, with the result that a net saving is effected in the total weight that must be carried. This is particularly important on long flights. The weight of the water-cooling system cannot be reduced materially but air-cooling offers a saving of between 0.65 and 0.75 lb. per hp.

A more significant measure of efficiency than the weight per horsepower of the engine alone, he said, would be the wet weight of the engine per horsepower plus the weight of the cooling-system per horsepower plus the combined weight of the fuel and oil per horsepower per hour. This figure, however, has no value except as an indication of the over-all efficiency of the powerplant.

In referring to air-cooled engines, Mr. Mead remarked that air-cooling is as logical for airplanes as water is for marine engines. The simplicity of direct cooling makes for dependability. Increased dependability and reduced weight are not so essential in motor-car work. If the radiator of a motor car leaks and the water runs out, it is necessary only to stop and refill it; the occupants of the car suffer no damage. A failure in the air, however, necessitating a forced-landing frequently has serious results. In aircraft work, too, extreme silence is not essential.

Mr. Mead included detailed descriptions of a large number of American and foreign types of aircraft engine with illustrations of many of the leading makes. His paper is printed in full on p. 496 of this issue of THE JOURNAL.

The Light Airplane and Low-Powered Flying

Mr. LePage, whose paper on the Light Airplane and Low-Powered Flying is also printed in this issue of THE JOURNAL, on p. 437, devoted his attention to a discussion of the development of light airplanes, the advantages of which, in his opinion, consist largely of obtaining from them new principles of design that may be embodied with confidence in larger airplanes.

During the war, which was responsible for the impetus given to aviation, maximum performance was the objective sought and this was attained by increasing the power of the engine rather than by improving the efficiency of the design. The cost of the upkeep and operation of the necessarily high-powered engines has retarded the progress of commercial aviation, which requires that freight and passenger-carrying air-liners shall be operated as economically as possible. Light airplanes represent the thin edge of the wedge in the development of ecomonically operated airplane of the low-powered type. The various features that enter into the successful operation of light planes were given detailed consideration and their relation to airplanes of larger size was discussed.

AERONAUTIC BANQUET A SUCCESS

C. M. Keys Interests Audience of Enthusiastic Members and Guests

The only social feature of the Aeronautic Meeting was the banquet, following the afternoon technical session. This event, which took place in the north ballroom of the Hotel Astor at 6 p. m. and which was attended by approximately 325 persons, was a very enjoyable and successful affair. Many distinguished European authorities, as well as a large number of American leaders in the aircraft industry, listened with great interest to the introductory remarks of Past-President Crane, who acted as toastmaster, and to the splendid address of C. M. Keys, president of the Curtiss Aeroplane & Motor Corporation, who was the sole speaker. At the speakers' table, in addition to Mr. Crane and Mr. Keys, were Gen. Mason Patrick, chief of Air Service; General Fechet, assistant chief of Air Service; Howard Coffin, representing the President's Air Board; Hugh Robertson, representing New York 1925 Air Races, Inc.; Godfrey Cabot, of the National Aeronautic Association; Paul Henderson, former Second Assistant Postmaster-General; Colonel Foulois, commanding officer of Mitchel Field; Commander H. C. Richardson, representing the United States Navy; Major Georges Thenault, of the French Embassy; Commander Calderara, of the Italian Embassy; Group Captain Scott, of the Canadian Royal Air Forces; Capt. P. E. Flandin, president of the Aero Club of France; and Orville Wright.

Toast to President Coolidge

President Coolidge's splendid initiative in connection with aviation was lauded by Toastmaster Crane in his opening remarks, at which time he proposed a toast to the President of the United States. Immediately the orchestra began to play The Star-Spangled Banner, and the audience rose.

In introducing the speaker, Mr. Crane said that the endeavor had been made to get a man of wide experience who could look at aviation from as many angles as possible and that with this thought in mind Mr. Keys had been chosen. Mr. Keys' address, which is full of timely interest, is printed in full elsewhere in this issue of The Journal. A brief summary of it is given below.

Popular Demand for Aviation

Mr. Keys characterized the present state of public opinion about aviation by saying that, so far as he knew, there is not any definite public opinion concerning it, but about a million ideas are afloat as to the various phases of aviation.

The biggest news of the year in the industry was the entry of Henry Ford into the commercial end of aviation, according to Mr. Keys, who said that this event is big news principally because the Ford interests were really answering what seemed to be a definite call from the public of the United States for aviation on a decent scale. The speaker told about editorials, to the number of 1625, from all parts of the Country, that had come into his office in the preceding month, and said that, practically without exception, they voiced the sentiment of the people that we must have aviation, both military and commercial, in this Country. He felt that giving aviation to the people in response to their demand may be a hard job but it will in the long run be a profitable and honorable job.

Referring to the aviation industry as a tremendously troublesome and noisy infant, he spoke of the fact that it gets more front-page publicity in a normal month, without paying for it, than any other trade could get in a normal year. With regard to the diversity of statements on aviation and the consequent confusion in the minds of the public, Mr. Keys stated that the people are constantly asking whether we are ahead of Europe or otherwise in our ability to create types of airships and engines and in our ability to build them. He said that we need not fear comparison in either engines or airplanes, because we have the men and the technical equipment and the technical knowledge to maintain a place alongside the great designing and engineering firms

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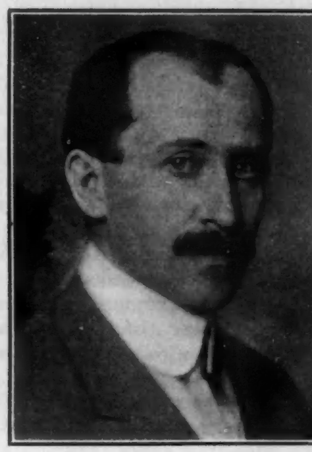
C. M. Keys



Orville Wright

of Great Britain and France. He went on to state, however, that France and England long ago adopted the theory that the heart of military aviation is the aviation industry, with the consequence that their policies have as their very foundation the maintenance of such an industry proportionate to their peace-time needs. They have concentrated the building of that industry upon the units that have maintained at all times strong engineering forces and created at all times new and useful types. The absence of such a policy in this Country is what constitutes the only difference between the situation in Europe and the situation here, according to Mr. Keys, who stated his belief that a change in this regard has already begun.

In this connection Mr. Keys spoke of the Navy General Board and the Army General Staff in their relation to aviation and cited instances to show the ignorance that has existed among them on this subject. He believed, however, that this condition is breaking down in both the General Board and the General Staff and expressed the view that the awakening of both the Army and the Navy on aircraft matters will probably go forward rapidly, with the result that in a very short time the most complete and accurate information concerning aircraft in the United States will not only be in the files of the General Board and the General Staff, but will also be in the minds and in the hearts of strong and forceful members of those boards.

AIR SERVICE MORE RELIABLE THAN RAIL

Air-Mail and Ford-Airline Facts Presented Orally and on the Screen

That air-mail and air-express services are not only faster but more regular and dependable than railroad passenger-trains after 80 years of development and operation of the latter, was the outstanding fact presented at the evening session of the Aeronautic Meeting. This was brought out

in statements by J. Parker Van Zandt, secretary of the Committee on Civil Aviation, of the Department of Commerce, who has made a comparative study of the Air-Mail Service and of passenger-train records, and by W. B. Stout, president of the Stout Metal Airplane Co., Airline Division of the Ford Motor Co.

Two motion-picture reels of the operation of the Ford airlines between Dearborn, Mich., and Chicago and Cleveland, established during the past summer, were exhibited to an interested audience of more than 300 members and guests. Mr. Van Zandt's address was illustrated by a number of charts projected on the screen to show the percentages of on-time arrivals of mail airplanes and railroad trains and also the persistence and strength of west and east winds and their effect on the reliability of the mail airplanes operating on various ground-speed schedules.

J. E. Whitbeck, superintendent of the Eastern Division of the Air-Mail Service, who was to deliver a paper on the operation of the Air Mail, was unable to be present as he and other officials of the Division were in western Pennsylvania directing the search for pilot Charles H. Ames, who was lost with his mail airplane in a fog in the mountains 6 days previously. Mr. Whitbeck's paper was read by Joseph W. Roe, professor of industrial engineering, New York University, who, with Mr. Van Zandt, is making a survey of commercial aviation for the committee appointed by Secretary Hoover.

Paul Henderson, formerly Second Assistant Postmaster General, who organized the Air-Mail Service and recently resigned to become general manager of the National Air Transport, Inc., of Chicago, acted as chairman.

Two distinguished visitors entered during the delivery of Mr. Stout's address and the Chairman introduced them to the audience as P. E. Flandin, president of the Aero Club de France, and Louis Breguet, manufacturer of the Breguet airplanes in France.

Mr. Henderson also read a telegram to the Society from Harris Whittemore, president of the Colonial Air Lines, of Naugatuck, Conn., announcing that his company had that day been awarded a contract by the Postoffice Department for the carrying of the Air Mail from New York City to Boston by way of Hartford, assuring the public of the company's purpose to fulfill the contract and the trust imposed upon it and promising that the rapid development of airways in New England would be the further object for which it would strive.

Ford Airline Pictures and Operating Data

After delivering his paper, which is printed in full in this issue of The Journal, Mr. Stout showed the motion pictures of the development of the Ford airlines, from the starting of the service to Chicago with one machine and one engine to the carrying of a complete Ford roadster, knocked-down, to Cleveland and its assembly there, ready to be driven away, in 51 min. Among the many incidents shown in the pictures were the starting of the airplanes at Ford Airport and their arrival in Chicago and Cleveland, loading and unloading the airplanes, the reassembling of the roadster, the Stout airplane factory and the new experimental shop at Dearborn. Mr. Stout gave a running comment on the pictures during their exhibition and replied to many questions from the audience.

He said that, while discussing the possibilities of air service, Mr. Ford said that the way to show what could be done was to start a line and asked if he could start a service between Dearborn and Chicago, the following Monday. This was done, with the only airplane and engine available. Now, he said, there are nine airplanes in operation on the two routes to Chicago and Cleveland. The airplane was scheduled to leave Dearborn at noon, but one day, shortly after the starting of the service, the machine being loaded and all ready to depart, it was sent away at 11:55 a. m. Later, Mr. Ford asked at what time it left and, being told, declared that if it was scheduled to leave at 12 o'clock it should start at that time; therefore a gong was installed at the starting-point and connected with the factory, where a button is pressed precisely at noon, and now the people in Dearborn and Detroit set their watches by the airplane.

The first trip to Chicago was made in 2 hr. 48 min. but the flying time now is 2 hr. 35 min. The terminal for the Chicago route is at Maywood, a western suburb, and it takes almost as long to truck the loads from the landing-field to the Ford plant in another outlying district as for the airplane to fly back to Dearborn. Airplane No. 1, said Mr. Stout, has now covered 60,000 miles in the air. The landing-speed of the machines, he said in reply to a question, is about 50 m.p.h., but the landing-speed is not of so much importance as the distance within which the airplanes can stop on the ground. As the picture showed one of the pilots descending from the airplane after a trip, the speaker said that on the following day, Oct. 8, the pilot was to fly a machine that had been bought by the John Wanamaker stores, from Dearborn to New York City for delivery. It was the first of 10 that would be used for service between the Wanamaker stores in New York City and Philadelphia, with probable later extension of delivery service to customers in Florida.

This brought an inquiry as to whether the Stout metal airplanes were for sale, to which Mr. Stout responded that they were for sale to incorporated airlines but not to individuals and that the company must know what the airplanes are to be used for before it will sell any. Numerous inquiries directed toward purchases had been received, he said, from persons whose intentions regarding the use of the airplanes were known and negotiations for sales were not entered into. Asked what the price of the airplane was, he said that, without engine, it was $22,500, which should come down later to $15,000. The ultimate price, he said, would depend upon the cost of the engine, which would be air-cooled; he thought that very few water-cooled engines would be used in new airplanes in another year.

Operating Cost and Depreciation

Some operating cost figures taken from the Ford Motor Co.'s cost sheets, with the compilation of which he had nothing to do, were given by Mr. Stout and aroused keen interest. The complete tabulation will be found in his paper, which is printed elsewhere in this issue. It shows that the average load carried was 945 lb., the average cost per mile flown was 36 cents, and the average cost per pound of load was 8.6 cents. These figures include a depreciation allowance of $2.50 per hr. on the engine. Replying to a question, Mr. Stout said that depreciation on the ship is figured on a basis of 300,000 miles, which is equivalent to about 3000 hr. and is considered very conservative, as he thought that an all-metal ship would last longer than the wood-framed airplanes that had already given that much service. Engine depreciation, he said, is the major item. There is no crystallization of the metal of the airplane, he stated in answer to another question. Whether or not crystallization occurs is dependent entirely upon the design and the resulting stresses. There is no more probability of crystallization in the plane than there is in the roof trusses of a powerplant in which there is constant vibration.

Mr. Backus asked if alloy-steels would be used altogether in metal airplanes or if carbon steels could be used. Mr. Stout responded that the difference in the coefficient of expansion of the two kinds of metal make it preferable to use duralumin throughout.

After a portion of the motion pictures had shown the pilot opening a pair of windows over the pilot's seat and emerging, a member inquired how long it would take to open the windows for a parachute jump. Mr. Stout replied that they could be opened in 1 sec., as they merely needed to be unfastened and the wind would blow them full open. The pilots are insured by the Ford Company, which carries most of its own insurance, but crash insurance is not covered; the best insurance against crashes is proper design, construction and inspection. The machine is stable against a side-wind but the landing-gear is being widened. The operating division is writing off a crash charge that is believed to be reasonable.

In response to several inquiries, it was stated that the fuel consumption was at the rate of about 4½ miles per gal.,

that the maximum weight of the ship, light and without water, was 5750 lb. and that, although the company had been using DeHaviland radiators, which were too small for the engines, no cooling trouble had been experienced. The fixed operating cost was $15 per hr., Mr. Stout said in reply to a question, and all of the engines used were Ford Liberty engines, because plenty of them were available; but they were rebuilt to bring them uptodate. The cost of the engine was about $2,000, and about $1,000 was expended in remodeling each of them. The engine is installed in a separate nose compartment and the powerplant is a complete unit; hence, to replace it, all that is required is to insert and tighten four bolts and connect the pipes.

Inspection Routine and Engine Depreciation

W. Laurence LePage asked for some information on the inspection routine, which Mr. Stout described, stating that the inspectors have printed sheets which include every item that anyone in the Ford plant could think of. After every trip, everything on the ship is inspected, the men going through with a light and examining every part of the construction, even to every bolt, and giving particular attention to the controls. The inspection takes 1 hr.

Commenting on this, Chairman Henderson said that the Air Mail inspection includes 100 items, of which 40 relate to the engine and 60 to the rest of the airplane, which, because of its different construction, probably requires more attention to the structure than does the metal airplane. The system is like the Stout system except that a second man checks the first man's inspection and the pilot has the right to reject the inspection and the checking and to ask for another inspection by other men.

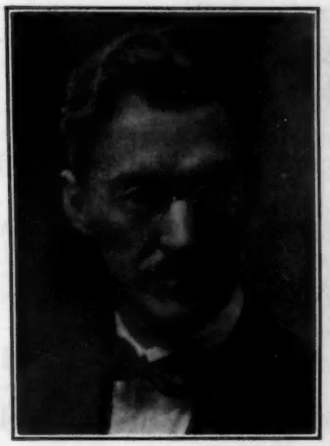
The lowest depreciation with the Liberty-engined airplanes in the Air Mail Service, said Mr. Henderson, was from $22 to $27 per hr. and about $7.50 was represented by Mr. Stout's $2.50 engine depreciation per hour. He was delighted to have discussion on depreciation, because it will be the greatest item of operating expense for some time to come. The National Air Transport lines will be maintained at the figures stated, he said, for some time.

Van Zandt Tells of Relative Reliability

Chairman Henderson then introduced Mr. Van Zandt, who investigated the airlines in Europe during the summer of 1924 and who was appointed, with others, by Secretary Hoover on the Committee of Civil Aviation of the Department of Commerce to study the development of airplane operation. Mr. Van Zandt then delivered his address, which is printed in full, with the charts as thrown on the screen, in this number of THE JOURNAL. He dealt with the relative reliability of the Air-Mail Service and of railroad passenger-trains in New York State and between New York City and Chicago, showing that, although only in its sixth year of operation in a pioneer field and with route facilities much below the standard to which they can be brought, the air service is much more

PAUL HENDERSON

J. P. VAN ZANDT



W. B. STOUT

J. E. WHITBECK

reliable in the matter of on-time arrivals at terminals than the railroad service that has been developed during a period of 80 years. He also showed the effect of prevailing westerly winds on the reliability of the air service as related to time-schedules based on ground-speeds ranging from 60 to 90 m.p.h., and closed with a warning that the new time-schedule for the night Air-Mail from New York City to Chicago is too fast; it should be based on a ground-speed at least 15 m.p.h. slower or the airplanes should have a speed of 15 m.p.h. faster than that of those at present in use, to make allowance for head winds from the west. The Air-Mail Service, he said, is not availing itself of its own experience and is risking its reputation for reliability by adopting a schedule based on a ground-speed of 83 m.p.h. westbound.

Replying to a question, Mr. Van Zandt said that, although the winds at night are less strong at the ground than in the daytime, their actual strength above 1500 ft. elevation is greater at night. It is not known to what extent head-winds affect passenger-train regularity, as there is a great paucity of data in the libraries regarding train reliability. It is probably true that locomotives have a reserve of power with which they can offset the effect of head-winds. Tremendous use could be made of varying winds at different altitudes, he said, if pilots could have immediate information regarding their direction and strength, and it was possible the development of radio communication would make this possible.

Air Mail Service Organization Discussed

After announcing Mr. Whitbeck's inability to be present, Chairman Henderson called for a vote of the meeting on the question whether Mr. Whitbeck's paper should be read by another, and, upon receiving an affirmative vote, asked Prof. Joseph W. Roe to read it. The paper was a survey of the operation of the Air Mail, with particular reference to the pilots; the ground-organization and its work, such as inspection; and the airways and airports and their equipment. The complete paper will be found in another part of this issue of THE JOURNAL.

SERVICE ENGINEERING MEETING

To Be Held in Cooperation with National Automobile Chamber of Commerce

Arrangements have been practically completed for the Service Engineering Meeting that will be held in cooperation with the National Automobile Chamber of Commerce at Hotel La Salle, Chicago, Nov. 9 and 10.

As shown by the program on p. 424, four technical sessions will be held, two under the auspices of the Society and two others under the sponsorship of the National Automobile Chamber of Commerce. It is believed that the topics to be discussed will attract widespread interest throughout the

NATIONAL MEETINGS CALENDAR

SERVICE ENGINEERING MEETING—Chicago—Nov. 9 and 10

AUTOMOTIVE TRANSPORTATION MEETING—Philadelphia—Nov. 13 and 14

ANNUAL DINNER—New York City—Jan. 14, 1926

ANNUAL MEETING—Detroit—Jan. 26-29, 1926

THE CARNIVAL—Detroit—Jan. 27, 1926

service-engineering fraternity; the speakers are men well qualified by virtue of their experience to present well-rounded analyses of the subjects that they have chosen.

Four Sessions Scheduled

The opening and closing sessions of the Meeting have been arranged by the Service Committee of the National Automobile Chamber of Commerce. G. F. Lord, of the Durant Motors, Inc., will address the opening session on the topic, Maintenance for the Protection of the Car-Owner's Investment. This paper will be followed by one entitled, Designing with Consideration for Repairmen's Tool Equipment, by D. C. Hinckley, of the Hinckley, Myers Co.

Engine Corrosion

From an analysis of the problems that now confront service engineers, it develops that the corrosion of parts in internal-combustion engines is of paramount importance. In view of the fact that comparatively little information on this topic has been available, the committee thought it advisable to offer the members an opportunity to hear of recent investigations along this line and to profit by an interchange of experiences of persons interested in this common problem. Two very excellent papers have been obtained, one to be presented by Frank Jardine, of the Aluminum Co. of America, and the second by M. A. Thorne, of the Tidewater Oil Co. A wealth of interesting and hitherto unpublished material relating to corrosion will be presented.

Engine and Car Troubles

Although automobiles have reached an advanced stage in their development and although extensive improvements have been made, certain difficulties and troubles still confront service engineers from time to time. Among these, noise is per-

SERVICE ENGINEERING MEETING PROGRAM

Hotel La Salle, Chicago, Nov. 9 and 10

Monday, Nov. 9

10:00 a. m.—Opening Session
- Maintenance for the Protection of the Car Owner—G. F. Lord, Durant Motors, Inc.
- Designing with Consideration for Repairmen's Tool Equipment—D. C. Hinckley, Hinckley, Myers Co.

1:00 p. m.—Luncheon

2:00 p. m.—Corrosion Session
- Corrosion in Internal-Combustion Engines—Frank Jardine, Aluminum Co. of America
- New Data on Engine Corrosion—M. A. Thorne, Tidewater Oil Co.
- Organized Discussion of Lubrication and Corrosion Topics

Tuesday, Nov. 10

10:00 a. m.—Trouble Diagnosis Session
- Diagnosis of Automobile Chassis Troubles—C. L. Sheppy, J. C. Talcott and Charles Pleuthner, Pierce-Arrow Motor Car Co.
- Engine and Car Troubles, Their Diagnosis and Cure—Carl Breer and John Squires, Maxwell-Chrysler Motor Corporation
- Prepared Discussion of Methods and Equipment for Investigating Engine and Car Troubles

1:00 p. m.—Luncheon

2:00 p. m.—Closing Session
- Automotive Fuel from the Service Standpoint—T. A. Boyd, General Motors Corporation
- New Devices for Improving Car Operation—Donald Blanchard, *Motor World.*

The Service Engineering Meeting in which the Society and the National Automobile Chamber of Commerce are cooperating will be *open to all* persons seriously interested in the topics under discussion. Members of the Society are urged to spread the invitation to attend the technical sessions. The Opening and Closing Sessions are under the direction of the National Automobile Chamber of Commerce; the Corrosion and Trouble Diagnosis Sessions are under the direction of the Society of Automotive Engineers.

Nov. 11 has been very courteously set aside by the Automotive Equipment Association as Society of Automotive Engineers and Service Men's Day. Members are invited to attend the Automotive Equipment Association Convention session on that day and will be offered an opportunity to inspect the Automotive Equipment Association Exhibition that promises to be of great interest to service men.

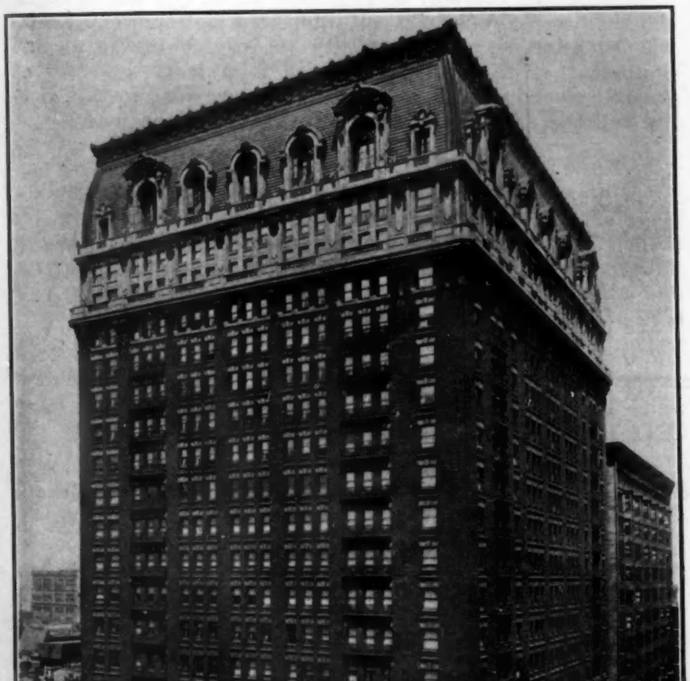
haps one of the most baffling. Members and guests will have an opportunity to hear an extensive discussion of the diagnosis of engine and car troubles and the choice of suitable methods for remedying them at the morning session of the Service Engineering Meeting on Nov. 10. Among those who will be responsible for a presentation of prepared material on this topic are C. L. Sheppy, Charles Pleuthner, and John C. Talcott, all of the Pierce-Arrow Motor Car Co., and Carl Breer and John Squires, of the Maxwell-Chrysler Motor Corporation. Included in this session will be a discussion of various systems for diagnosing the different forms of trouble to which motor vehicles are subject and remedying them.

Fuels To Be Discussed

T. A. Boyd, of the General Motors Corporation, will present a paper at the afternoon session on Nov. 10 on Automotive Fuels from the Service Standpoint. This paper, coming from an authority on fuels, at a time when the topic is uppermost in the minds of many engineers, should attract considerable interest and should form the basis for a spirited discussion. The second paper of the closing session will be presented by Donald Blanchard, of *Motor World*, and will deal with the Year's Development in New Devices for Improving Car Operation.

Exposition Open to Members

Through the courtesy of Commissioner W. M. Webster, an invitation has been extended by the Automotive Equipment Association for the members of the Society to attend the Association's convention and exposition of equipment on Nov. 11 at the Coliseum in Chicago. This day has been set aside by the Automotive Equipment Association as Society of Automotive Engineers and Service Men's Day. Members will attend a short convention session in the morning, after which they will be free to inspect the exposition of equipment that promises to be greater and more interesting than any that have in the past been arranged by the Association.



Hotel La Salle, Chicago
The Service Engineering Meeting, under the Joint Auspices of the Society and the National Automobile Chamber of Commerce, Will Occur Here, the Dates of the Four Sessions Being Nov. 9 and 10

An Open Meeting

The Meetings Committee has endeavored to reflect the wishes of Society members by inviting all interested persons to attend the technical sessions of the Service Engineering Meeting and to share in the benefits that may be derived therefrom.

TRANSPORTATION MEETING SOON

The Benjamin Franklin Hotel, Philadelphia, To Be Site; Nov. 13 and 14, the Dates

An unusual amount of interest is being shown in the arrangements for the Society's Automotive Transportation Meeting that has been scheduled by Chairman Herrington and his committee for Nov. 13 and 14 at the Benjamin Franklin Hotel, Philadelphia.

As indicated by the program on p. 426 three technical sessions, a Transportation Banquet and an inspection visit have been scheduled. The principal topics to be discussed include standardization, freight handling and motorcoach operation, although many other items of interest to transportation engineers will be raised for discussion by qualified persons with whom the committee has arranged for special presentations.

Standardization Session

Opening with an address of welcome by President Horning, the first session on the morning of Nov. 13 will be under the chairmanship of Past-President B. B. Bachman, engineer of the Autocar Co.

E. W. Templin, motorcoach engineer of the Six Wheel Co., has prepared an interesting analysis of the manufacturer's attitude toward standardization.

H. F. Fritch, of the Boston & Maine Railroad, who has had considerable experience in the operation of motorbuses in connection with the service of the railroad, will discuss this operation and will present his views concerning standardization features as they enter the various phases of successful operation.

Robbins B. Stoeckel, commissioner of motor vehicles of the State of Connecticut, will present views of motorcoach standardization and regulation from the standpoint of State authority. Mr. Stoeckel has a number of very striking points and will illustrate them by charts and pictures.

Thus the topic of standardization of equipment will be analyzed from the standpoint of the manufacturer, the operator and State authority.

Freight-Handling Session

Under the chairmanship of F. C. Horner, of the General Motors Corporation, the afternoon session on Nov. 13 will be devoted to the consideration of freight handling by automotive equipment. Joseph L. Scott, of Scott Bros., Philadelphia, who has had a very extensive experience in handling of freight in coordination of the activities of the Pennsylvania Railroad, will present a picture of the problems that have developed in connection with this work and will bring to light many important facts concerning a phase of motor-vehicle operation about which comparatively little is known.

The handling of containers and less-than-carload freight will be the subject of a paper by F. H. Kulp, of the Kulp Lines, Buffalo. Very few transportation men possess the qualifications of Mr. Kulp to discuss the real problems involved in this topic.

Vauclain at Banquet

The committee in charge of the Transportation Banquet that will be held at the Benjamin Franklin Hotel, commencing

THE BENJAMIN FRANKLIN HOTEL, PHILADELPHIA
The Three Technical Sessions of the Automotive Transportation Meeting and the Transportation Banquet Will Be Held Here on Nov. 13 and 14

at 6:30 p. m., Friday, Nov. 13, has arranged an attractive program of speakers and entertainment. The members will be honored by the presence of President Horning, whereas A. F. Masury, of the International Motor Co., will act as toastmaster.

Great credit is due the committee for obtaining the consent of Samuel M. Vauclain, president of the Baldwin Locomotive Works, to address the Transportation Banquet. It would be difficult to find a person of international prominence who would be more acceptable to the Society than Mr. Vauclain. Do not fail to hear him.

Dr. E. J. Cattell, an after-dinner speaker of rare capability, whose popularity has been a sensation, will also address the Banquet.

TICKETS GOING RAPIDLY

The demand for tickets to the Transportation Banquet at $3.50 each is expected to be greater than the supply. Many applications for tickets have already been received, and it is recommended that members who wish to avoid disappointment forward their applications at once to the New York City office with the proper remittance. An application blank will be found in the latest two issues of the *Meetings Bulletin*.

MOTORCOACH-OPERATION SESSION

The final technical session of the Automotive Transportation Meeting will be on the topic of motorcoach operation and will be under the chairmanship of A. J. Scaife, of the White Motor Co. It would be difficult to find a transportation man who is not eager to learn the latest information pertaining to the operation of gasoline-electric motorcoaches. A splendid paper on this topic has been prepared and will be presented by R. H. Horton, Philadelphia Rural Transit Co. Uptodate facts and figures are included in this paper.

Operation data pertaining to six-wheel vehicles will be revealed by W. F. Evans, Detroit Motorbus Co. Mr. Evans is expected to bring with him several reels of motion pictures showing the operation of this type of vehicle.

GASOLINE-ELECTRIC INSPECTION

Through the courtesy of President R. H. Horton, of Philadelphia Rural Transit Co., all interested members and guests will be afforded an opportunity to inspect the plant and equipment of that company which is a large operator of gasoline-electric vehicles. Conveyances provided by Mr. Horton will transport the members to and from the plant.

ALL WELCOME

All persons interested in automotive transportation problems, whether members of the Society or not, are cordially invited to attend the technical sessions of the Automotive Transportation Meeting and to participate in the Banquet and the inspection visit. It is hoped that a large number will take advantage of this opportunity.

AUTOMOTIVE TRANSPORTATION MEETING PROGRAM

Benjamin Franklin Hotel — Nov. 13 and 14 — Philadelphia

Friday, Nov. 13

10:00 a. m.—STANDARDIZATION SESSION
- B. B. Bachman, Autocar Co., Chairman
- The Manufacturer's Attitude toward Standardization—E. W. Templin, Six Wheel Co.
- The Motorcoach and the Railroad; Influences of Standardization upon Operation—H. F. Fritch, Boston & Maine Railroad
- Pressing Motor Vehicle Problems from the Viewpoint of a State—R. B. Stoeckel, Commissioner of Motor Vehicles, State of Connecticut

1:00 p. m.—AUTOMOTIVE TRANSPORTATION LUNCHEON

2:30 p. m.—FREIGHT HANDLING SESSION
- F. C. Horner, General Motors Corporation, Chairman
- Freight Handling with Trucks—Joseph L. Scott, Scott Bros.

Friday, Nov. 13

2:30 p. m.— FREIGHT HANDLING SESSION—(*Concluded*)
- Handling of Containers and Less-than-Carload Freight—F. H. Kulp, Kulp Transportation Lines

6:30 p. m.—AUTOMOTIVE TRANSPORTATION BANQUET
- A. F. Masury, International Motor Co., Toastmaster
- Speakers: Samuel M. Vauclain and Dr. E. J. Cattell

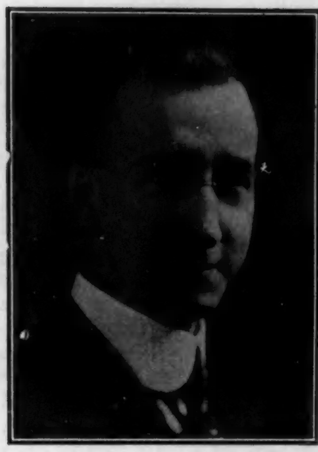
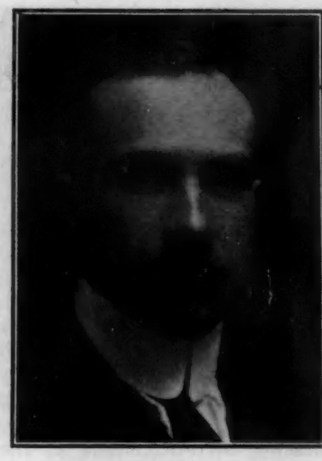
Saturday, Nov. 14

10:00 a. m.—MOTORCOACH OPERATION SESSION
- A. J. Scaife, White Motor Co., Chairman
- Operation of Gasoline-Electric Motorcoaches—R. H. Horton, Philadelphia Rural Transit Co.
- Operation of Six-Wheel Motorcoaches—W. F. Evans, Detroit Motorbus Co.

1:00 p. m.—AUTOMOTIVE TRANSPORTATION LUNCHEON

2:30 p. m.—INSPECTION VISIT
- Plant and Equipment of the Philadelphia Rural Transit Co.



Edwin C. Wood
Chairman

Grahame B. Ridley
Vice-Chairman

W. S. Crowell
Secretary

Charles W. Gebhardt
Treasurer

OFFICERS OF THE RECENTLY FORMED NORTHERN CALIFORNIA SECTION

PENNSYLVANIA SECTION ACTIVE

Intensive work on the part of the members of the Pennsylvania Section will be largely responsible for the success of many features of the Transportation Meeting. Without exception the members of the local organization have cooperated to the fullest extent and are showing an interest in the undertaking that presages well for its success.

ANNUAL MEETING DATE CHANGED

Meetings Committee Definitely Schedules This Event for Detroit, Jan. 26 to 29

At a recent session, the Meetings Committee discussed plans for the 1926 Annual Meeting and decided definitely to change the date to Jan. 26 to 29, with General Motors Building, Detroit, as the meeting place. A number of very interesting topics were selected for discussion at the technical sessions, and recommendations as to speakers were made.

THE CARNIVAL

General plans were formulated for holding a Carnival on the evening of Jan. 27 during the Annual Meeting. Additional details concerning this event and the other features of the Annual Meeting program will be disclosed in due course.

NORTHERN CALIFORNIA SECTION FORMED

San Francisco Group Formally Made a Section at an Enthusiastic Meeting

Indicative as it is of the healthy growth of the Society, the advent of a new Section of the parent body is indeed a welcome event. We are glad, therefore, to say: Meet the new Northern California Section, which held its inaugural meeting on Sept. 28 at the Hotel Richelieu in San Francisco. H. L. Horning, president of the Society, delivered an inspiring address, having made a special trip from the East so as to be present at this first formal Section meeting. About 200 members and guests attended the meeting and the dinner that preceded it, the occasion being most auspicious in all respects. A membership of 130 has already been attained, and headquarters have been established at the Engineers Club in San Francisco.

W. W. McDonald, president of the membership committee of the San Francisco district, presided at the business session with which the meeting was opened, and read the telegrams of congratulation sent by other Sections of the Society. The following officers were elected: Edwin C. Wood, chairman; Grahame B. Ridley, vice-chairman; Charles W. Gebhardt, treasurer; and W. S. Crowell, secretary. A brief address was delivered by Pliny E. Holt, of the Holt Tractor Co. Mayor James Rolph designated Ralph McLaren, who has represented various engineering societies in the community, as his personal representative at the meeting.

After outlining the work that the Standards Committee has carried on, President Horning quoted statistics regarding the automotive industry which were of great interest and mentioned a number of the automotive activities that had their beginning in California, among them being the Liberty engine, the Holt caterpillar tractor and the Ensign carbureter. It was also said that the motorbus had its original use in California, that the multiple gear was perfected there, and that California at present has the most extensive lines of motor-vehicle freight-transportation.

California faces a tremendous problem in the development of a market system. Problems of distance, of time and of the conservation of energy are involved. The extremes of variety in the topography of the State make the provision of adequate transportation even more difficult, inclusive as they are of level, hilly, mountainous and desert sections. To solve the problem of economic hauling over long routes under varying conditions, motor trucks have been used for purposes undreamed of by their manufacturers, and six-wheel and even eight-wheel trucks and trailers are used. The object has been to haul a larger load for a greater distance and to increase the pay load.

President Horning mentioned the problem the railroads are facing in regard to the economic hauling of freight for distances up to 100 miles, and discussed the means that are being adopted to overcome this difficulty by the use of motor trucks, motor rail-cars and motorbuses. In closing, he outlined to those present the responsibilities of the Section and its members.

Ralph McLaren, who is a contractor, is reported as having declared that the motor truck has decreased the cost of building, because of its ability to lessen the cost of transporting building material and to deliver it at greater speed than was formerly attainable. It also enables the contractor to receive his building materials in continuous consignments of relatively small bulk as he needs them, with the minimum amount of delay. He also credited the motor truck with reducing traffic congestion because of its ability to handle a greater volume of material in less time, which reduces the number of hauling units and thus minimizes congestion.

It was reported that the Section would devote considerable attention in the near future to maintenance and operating problems, recommending changed practices when these seem advisable and basing such recommendations on the experience of the owners of motor vehicles under actual field conditions.

THE SMALL CAR A LIVE TOPIC

Cleveland Section Turns Out in Force in Bad Weather to Discuss It

Despite bad weather, the attendance at the monthly meeting of the Cleveland Section on Oct. 19 was larger than usual. Those who braved the elements were rewarded by hearing an interesting paper on the Small Car, which was presented by O. E. Hunt, chief engineer of the Chevrolet Motor Co. The meeting followed a dinner of attending members at the Hollenden Hotel. In his address, Mr. Hunt predicted that a 1000-lb. three-passenger automobile may be the future American small car and that, if vibration in a four-cylinder engine cannot be eliminated, the small car will have a six-cylinder engine. The public is demanding a small car that will afford the comfort of a large car, he said, and the small car, in placing an automobile at the disposal of every family, has become the most important problem in the automobile industry. The problem is no longer that of producing an automobile to sell at a lower price but to produce a better car for the present price.

After the conclusion of the paper much interested and profitable discussion of the subject was given, indicating that the small car is receiving considerable serious attention at the present time, doubtless owing to the increasing traffic congestion and to the position attained in the small-car field by England and France.

CHICAGO SECTION WINS AT GOLF

Annual Get-Together Outing and Dinner with Milwaukee Section a Grand Success

An enthusiastic crowd, a beautiful day, a valiantly contested golf tournament, an enjoyable dinner, good-fellowship and some snappy impromptu talks made the annual get-together meeting of the Chicago and Milwaukee sections at the Wilmette Golf Club in the beautiful Skokie section of the shore of Lake Michigan on Oct. 23 a grand success.

The golf tournament was won by the Chicago Section, although the final victory was opposed determinedly throughout by the Milwaukee Section. The prize winners were: First, E. H. Ehrman, of the Standard Screw Co., Chicago; second, P. S. Tice, of the Stewart-Warner Speedometer Corporation, Chicago; and third, C. H. Jorgenson, of the Dole Valve Co., Chicago. A valiant attempt to carry off the prize for his Section was made by Julius J. Goetz, of the Western Metal Specialty Co., Milwaukee, but it was unsuccessful. Ralph C. Rose, of Milwaukee, laid claims to a birdie on one hole.

After the tournament an excellent dinner was served and was enlivened by great good-fellowship that was stimulated by several brief talks on the advantages of acquaintanceship and cooperation in business.

The Chicago Section acted as host to the Milwaukee Section, returning the similar courtesy extended to it in the past by the Cream City members at the Kenosha Country Club and on other occasions. Use of the Wilmette golf course was secured through the efforts of H. O. K. Meister, of the Chicago Section, and arrangements were made with the Chicago & Northwestern Railway for its train leaving Milwaukee at 10.30 to stop at Wilmette, Ill., where local transportation to the golf club was provided. Buffet luncheon was served at the club; then came the golf tournament, for which the prizes were put up by the Chicago Section.

This was the first meeting of the Chicago Section under the new administration and the special efforts that were put forth to draw out a large attendance and to provide an unusual program were rewarded with marked success, as indicated by the joint report of the affair made to THE JOURNAL by F. G. Whittington and A. C. Wollensak, the secretaries, respectively, of the Chicago and Milwaukee sections.

ORDNANCE DEMONSTRATION WITNESSED

Pennsylvania Section and Army Ordnance Association Visit Aberdeen Proving Ground

Members of the Pennsylvania Section and their guests to the number of 75 made a trip from Philadelphia to Aberdeen, Md., on Oct. 2 to attend the seventh annual meeting of the Army Ordnance Association and see the exhibition and demonstrations of ordnance as made by the Bureau of Aeronautics of the Navy and the Ordnance Department, Chemical Warfare Service, Field Artillery, Coast Artillery, Air Service and Signal Corps of the Army.

The trip was made in a gasoline-driven railcar furnished for the occasion by the J. G. Brill Co. as a result of the efforts of C. O. Guernsey, chairman of the Section and chief engineer of the automotive car division of the company. The car was driven by a 6 x 7¼-in. engine designed by the Brill Company and had no difficulty in maintaining the scheduled speed of 60 m.p.h., according to Adolph Gelpke, secretary of the Section, who states that the operation of the car was most interesting to all of the members on the trip, a large group watching its performance at all times.

Attendance at the exhibition and demonstrations of ordnance was at the invitation of the Army Ordnance Associa-

SCHEDULE OF SECTIONS MEETINGS

NOVEMBER

4—MILWAUKEE SECTION—Engine Lubrication—Thomas E. Coleman.
5—DETROIT SECTION—A Possible Solution of the Headlight Problem—H. M. Crane.
6—SOUTHERN CALIFORNIA SECTION—Road Construction and Destruction with Special Reference to Motor-Vehicle Traffic—J. E. Jellick and Chris P. Jensen.
12—INDIANA SECTION—Aviation Transportation—W. B. Stout and J. Parker Van Zandt.
17—BUFFALO SECTION—Dinner Meeting held in conjunction with Engineering Society of Buffalo. Present-Day Commercial Aviation—J. Parker Van Zandt.
19—NEW ENGLAND SECTION—Summary of Rear-Wheel Dynamometer-Tests of 100 Motor Vehicles—Prof. E. H. Lockwood; The Toxic Effect of Motor-Vehicle Exhaust—L. E. Crooks.
20—WASHINGTON SECTION—Testing of Automotive Equipment at the Proving Ground—John K. Christmas.
24—NORTHERN CALIFORNIA SECTION—Mechanical Traffic Control—Capt. Henry Gleason and William H. Marsh.
27—CHICAGO SECTION—Highway Safety Meeting.

DECEMBER

10—INDIANA SECTION—High-Duty Engines—Fred S. Duesenberg; additional talks by experts from McCook Field and the General Electric Co.

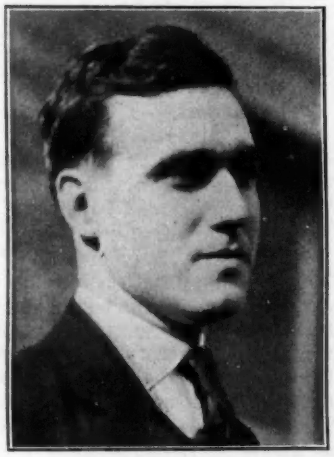
tion. The demonstrations included firings with a 3-in. anti-aircraft gun against a sleeve target towed by an airplane, the gun being mounted on a trailer; the firing of one round from a 14-in. gun on a disappearing carriage, firing of one round from a 16-in. coast-defense gun, the laying-down of a smoke curtain by a Martin bombing airplane, a parachute jump from an airplane, dropping of 600-lb. demolition bombs and smoke bombs from airplanes, the firing of machine-guns against free balloons and tank armor, firing of ground-type pyrotechnics used for signaling purposes, night firings of 0.30 and 0.50-caliber tracer bullets and 3-in. tracers, ground pyrotechnics, the firing of smokeless and flashless charges with 75 and 155-mm. guns, and demonstrations with the Livens projector and hand-grenades.

There were exhibitions of and maneuvers with mobile ordnance repair shops, military tanks, tractors and trailers, gun carriages, cross-country passenger and cargo vehicles, and mobile artillery.

GALA DAY FOR THE DETROIT SECTION

General Motors Exhibits Proving Grounds for Road Testing, and Banquet Follows

Facilities and methods of making road-tests of motor vehicles were demonstrated and discussed for the benefit of 450 members and guests of the Detroit Section on Oct. 1, when those in attendance were taken for long rides over the various test roadways and hills of the 1125-acre proving grounds of the General Motors Corporation near Detroit and afterward royally entertained at dinner in the large garage on the grounds which had been specially decorated for the occasion. A reception committee of representative General Motors Corporation officials made everyone welcome, C. F. Kettering personally piloted many loads of engineers over the test roads in a 20-passenger motorbus, a paper by O. T. Kreusser, of the General Motors Research Corporation, descriptive of the grounds and the test methods was read and discussed following the dinner, and the entire affair was at once profitable and thoroughly enjoyable. Representative engineers of many companies prominent in the industry were present, including men from Buffalo, Cleveland, Toledo, Indianapolis and Chicago, and the percentage of men of high rank in the industry was large. A photograph showing some of those who attended the meeting viewing the grounds from the top of one of the test hills is reproduced in Fig. 1.


O. T. KREUSSER

In beginning his description, Mr. Kreusser said that the proving grounds provide a place where road conditions are suitable for obtaining data that can be interpreted accurately, compared with similar data and used constructively. Adequate facilities are provided and ideal road-conditions have been established so that motor-vehicle tests involving endurance, speed, acceleration, hill climbing and riding-quality and other comparative tests can be made. Conditions are such that tests can be repeated from day to day, thus compensating for the variations of the weather and other factors. Complete and conclusive tests can be carried out readily and promptly, and the results are free from guesses and personal opinions.

The speed track, 20 ft. wide and nearly 4 miles long, has a surface mainly of Tarvia. Traffic is in one direction, clockwise. The turns are banked as shown in Fig. 2 and can be driven over safely at a speed of 65 m.p.h., the high-


FIG. 1—AT THE TOP OF ONE OF THE TEST HILLS
The Members Were Driven to This Spot and Given an Opportunity To Obtain a General View of the Proving Grounds and Were Then Driven Back to the Garage

speed cars passing the slower traffic by using the well banked part of the roadbed.

The 1⅜-mile concrete straightaway course runs east and west and is equipped with graveled loops at each end so that runs can be continued in either direction without gearshifting or stopping; all tests are run in both directions and then averaged to cancel out the effects of wind. It is over this course that acceleration, deceleration, rolling friction, riding-quality, fuel economy at fixed speed, minimum speed, maximum speed and similar tests are carried out. Another interesting facility is the concrete under-water roadway, which is 200 ft. long with 100 ft. of level section 12 ft. wide equipped with parapets to permit flooding to a depth as great as 2 ft. Special tests can be made here by driving vehicles through varied depths of water.

Three test hills having continuous accurate grades furnish means for measuring engine power comparatively, under driving conditions. A portion of one hill, which has a continuous accurate spiral grade of 11.6 per cent from the bottom to the top is illustrated in Fig. 3. An endurance-test route called the "hill road" winds through the southern portion of the property and connects the test hills with the speed loop: gradients as high as 24 per cent are included.

Mr. Kreusser said further that the proving-ground activities include the carrying on of endurance tests and experimental-car operation by each division of the Corporation, and the comparative engineering and endurance tests of such cars in current production as may be of interest. He enumerated the various tests, and stated many details of the methods of test procedure. It is expected that his paper, together with illustrations of some of the instruments used, will be published in a later issue of THE JOURNAL.

The members of the Detroit Section agreed that this meet-


FIG. 2—A TURN ON THE SPEED TRACK
Owing to the Fact That the Curves on the Speed Track Are Steeply Banked, Cars Can Be Driven around the Turns Safely at a Speed of 65 M.P.H.

FIG. 3—THE GRADE-TEST HILL
The Roadway Is Designed So As To Have a Constant Accurate Spiral Gradient of 11.6 Per Cent from the Bottom to the Top of the Hill

ing was one of the must successful events in the history of the Section, and they were highly appreciative of the generous hospitality shown them by the General Motors Corporation.

RADIO TRANSMITS VISIBLE SIGNALS

Dayton Section Informed of the Latest Practice in Aerial Navigation

Radio beacons as an aid to aerial navigation, the shielding of radio receiving sets from ignition noises and the transmission of visible signals by radio, were some of the high points of the paper delivered at the meeting of the Dayton Section held on Oct. 21 at the Engineers Club. These and other interesting features of radio development were ably presented by Capt. W. H. Murphy, of the Army Signal Corps, who is in charge of the radio laboratory at McCook Field. His paper was entitled The Use of Radio for Aerial Navigation and Military Purposes.

Captain Murphy's experience during and since the war makes him exceptionally well qualified to speak authoritatively concerning the latest developments of wireless signalling, and he presented much interesting and profitable information to the members and their guests who were in attendance at the meeting and the dinner that was held earlier in the evening.

AIRCRAFT-ENGINE DEVELOPMENT

Recent Progress Authoritatively Described to Washington Section Members

Weight comparisons between air-cooled and water-cooled aircraft-engines on a ready-to-fly basis emphasize the desirability of eliminating the plumbing, according to the telegraphic report of the paper on Aircraft-Engine Development presented by Lieut-Com. E. E. Wilson, U. S. N., at the Washington Section meeting held on Oct. 23 in the auditorium of the Cosmos Club. Commander Wilson is at present in charge of aircraft-engine development in the Bureau of Aeronautics, Navy Department, in the City of Washington, and is especially competent to review recent progress. It was said that the useful life of engines has been multiplied by six, during Navy development.

Fuels were discussed particularly in respect to their antiknock properties. Regarding gasoline bought on a distillation-curve basis, it was said to continue to show worse knocking characteristics.

Engine-performance improvement and improved weight-power ratios were reported as being due more to rational development than to invention. The spark-plug problem still remains unsolved for air-cooled engines, because the extreme variation of temperatures causes the spark-plugs either to foul or to preignite the fuel-mixture charge.

Numerous illustrations were shown on the screen, as well as a motion picture depicting the adverse conditions that naval flying equipment must encounter.

Seventy-five members and guests were in attendance, and a number of men prominent in aviation circles participated in the discussion that followed the presentation of the paper. Among these were Rear-Admiral W. A. Moffett, who is in charge of the Bureau of Aeronautics, and L. M. Woolson, aeronautical and research engineer for the Packard Motor Car Co. A. W. S. Herrington was elected as the representative of the Section on the Sections Committee of the Society.

FLYING MEET ON THE COAST

Airplane Maneuvers Part of Program of Southern California Section Meeting

Demonstrations of warming-up and stunt and formation flying with naval airplanes, a technical meeting with three addresses on aviation topics, a visit to an airplane factory and a dinner and dance provided a day and evening of unusual entertainment and instruction for about 150 members of the Southern California Section on the occasion of its monthly meeting on Oct. 10.

The commander of the naval aviation field at San Diego sent two airplanes by air to Clover Field, the Army aviation ground, on the morning of Saturday the 10th, with one of the speakers for the technical session, and another speaker flew from Rockwell Field, the Army air station at San Diego, with several airplanes.

One of the Navy machines was a fighting airplane, Model TS, driven by a 220-hp. air-cooled engine. After a demonstration was made to show the short time that is required to warm-up the engine, the pilots took some of the machines up to demonstrate their great maneuverability and turned forward and backward loops, turned over sidewise, did double-twists and performed other spectacular evolutions. There was also some formation flying by the Army department.

When the members of the Section had examined the airplanes, the technical meeting was held in the Army club room at Clover Field. Lieut. Leslie P. Arnold, one of the Navy's round-the-world fliers, spoke on the Air Service As the World Fliers Saw It; Lieut. Hugo Smith spoke on the Relations of Aircraft Engines to the Specific Needs of Naval Aviation, and D. W. Douglas, of the Douglas Co., spoke on the Present Phase of Commercial Aviation.

Following the meeting, the members visited the airplane factory of the Douglas Co. and later drove to the Santa Monica Athletic Club for dinner and to dance. About 75 attended the dinner.

In all, it was a very successful meeting.

TRAFFIC CONGESTION AND ITS CONTROL

National Regional and Local Phases Discussed Before Metropolitan Section

Control of traffic, in its National, regional and local aspects, received a thorough discussion at the October meeting of the Metropolitan Section held at the Hotel Majestic, New York City, on Oct. 15. The National or Federal organization was explained by John C. Long, secretary of the traffic planning committee of the National Automobile Chamber of Commerce; the cause and effect of congestion and the plans for relieving it were described by Harold M. Lewis, executive engineer of the regional plan of New York City and its environs of the Russell Sage Foundation; and the problems encountered in handling freight at the various railroad terminals in New York City were vividly depicted by Major

Elihu Church, transportation engineer of the Port of New York Authority.

One would not think of operating a railroad line without an adequate crew of dispatchers, a standardized signal system and a coordinating superintendent, asserted Mr. Long; but inasmuch as motor vehicles are controlled by individual owners, the regulation of traffic becomes very complicated. The only way in which it can be done is through the Government with the consent of the men who drive the machines. A constant educational campaign must therefore be carried on so that the public will know why the various regulations and developments are advisable and necessary.

But nationally controlled regulations and standardization can serve only as a guide. Railroads must work out the details of their own systems, and bodies operating in the highway field do so only in an advisory capacity, getting things accomplished by mutual consent.

Influential Organizations

The four chief influences on the engineering side of the problem, said Mr. Long, are the Society, the Highway Research Board, the Association of State Highway Officials and the United States Bureau of Public Roads. Within the Bureau of Public Roads is a group, which, he said, renders more service to the general public than any other group in the Government. This is the Federal Aid System, which works with the different State authorities on various phases of highway research and is planning the Federal Aid Highway Program of the Country.

The Federal Aid System plans eventually to provide a main highway that will pass through or touch upon every community of the United States having a population of 5000 or more. Congestion will thus be relieved at certain specific centers and the flow will be better distributed. About one-fifth of this program has already been completed, and not more than 10 or 15 years will be needed to finish the remainder. Eventually about 175,000 miles of road will be linked together.

Participating in this program is the Association of State Highway Officials, who are the executives on the firing-line and know what the local conditions are. The Highway Research Board keeps fully informed as to the best kinds of road to withstand certain conditions, the most successful methods of mixing concrete, the latest practices for preventing damage by frost, and kindred subjects. All such information is made available to local engineers at a centralized point.

Other National Associations

Other National Associations are concerned chiefly with two objects: (*a*) seeing to it that the human factor is properly considered and (*b*) arousing the human factor to the desirability of and the necessity for being considered. Among these bodies are included the various groups of motor-vehicle commissioners, one of which is called the Eastern Conference of Motor-Vehicle Administrators, the International Association of Chiefs of Police, the National Safety Council, the American Automobile Association, the National Bureau of Casualty & Surety Underwriters, the American Railway Association and the American Electric Railway Association. The National Automobile Chamber of Commerce functions as a research bureau in the traffic and safety field, he added. The National Conference on Street and Highway Safety was called by Secretary Hoover in order that ideas on the subject might be pooled and made readily available.

Mr. Long believes that the situation may be looked upon with optimism, that traffic troubles are now at their peak, that the technique of handling traffic is developing rapidly and that its success lies in the hands of engineers.

Congestion

In discussing the causes, effects and methods of relieving congestion, Mr. Lewis defined congestion as "unregulated and unplanned concentration." It can be relieved, he said, by greater concentration, not of the entire mass but of its individual parts; by sorting out and separating different types and routings of traffic. If different types were concentrated along routes planned primarily for them and laid out to furnish direct connection between separate populated districts, greater efficiency and freedom would result.

It was estimated that during the 24 hr. of a 1924 business day, 204,750 vehicles came into the part of Manhattan south of 59th Street, said Mr. Lewis. If this traffic moved in a single lane at 20 m.p.h. with the minimum spacing between the cars, the line would extend from New York City to beyond Salt Lake City. In the most congested part of the day, 36,000 vehicles were estimated to be within this area. Of the highways leading from the business section, the heaviest traffic was found to be on the Boston Post Road, the Albany Post Road and the Lincoln Highway, where it varied from 1400 to 1600 vehicles per hour. In the last year efforts have been made to divert traffic from the central avenues of Manhattan to those along the water-front, Mr. Lewis continued. At a cross-section taken at 48th Street, the total capacity of all the avenues in 1924 was only 33 per cent greater than the traffic count taken in 1923.

Ratio of Population to Cars in Use

Based upon population, the number of persons per car in 1923 was 16 in New York City and varied from 9 to 21 in the different boroughs, these values being about one-half what they had been 4 years previously. The entire region averaged about 11 persons per car. If the population should reach 12,000,000 in 1935, the estimated registration would be 3,150,000 vehicles. Among the instances of the effect of congestion were cited a trip, from Kingston, N. Y., to South Brooklyn on a holiday, on which 14 hr. was required to travel a distance of 100 miles; and a trip from Jackson Heights to Garden City, about 15 miles, that required 3 hr. on a Sunday afternoon. Many large plants were said to have moved from Manhattan and Long Island to New Jersey to obtain better transportation facilities.

Traffic control in the main business centers having already been carried to the maximum desirable limit, such methods of restrictive regulation as limiting the unloading of trucks from the street surface on busy thoroughfares, further limiting of parking and the segregating of various types of traffic were suggested as possible of utilization to a greater extent. The most positive method of relief, said Mr. Lewis, is by physical improvements to the highway system, such as by-passes around central congested districts, making use of the water-fronts, separating the grades and widening the streets.

Increase of Motor Vehicles

Major Church devoted his attention to specific instances of the results of traffic congestion, and showed conclusively the losses of time and money caused by it. In 20 years, he said, the total output of motor trucks in the United States has increased from 411 to more than 250,000. He believed that motor vehicles would make a greater change in the transportation methods of the United States, as compared with those of the railroads, than did the railroads, as compared with the methods of the stage coach. When the railroads began operation, the officials had no idea of the development that would take place; and their vision today, he added, is not very clear. In his lifetime he has seen three Grand Central stations at 42nd Street and Park Avenue, and the third has already nearly reached the saturation-point, so that plans have been suggested for diverting traffic to Long Island City and the Bronx.

Motor-truck traffic is so dense in some sections of the city, continued Major Church, that operators refuse to send their trucks there, not knowing when they can get them out. One result is that 73 out of every 100 trucks on West Street are now drawn by horses. Trucking is measured by time not by distance and the driver figures whether it will take 1 hr. or 5 hr. to make a delivery rather than whether the distance is 1 or 5 miles. Although a truck may be capable of carrying 5 tons, of going 20 m.p.h., and of working 8 hr. per day, the actual load carried is seldom more than 1 or 1½ tons; the speed, due to traffic congestion, not more

than 4 m.p.h.; and the running time, due to the time taken up in loading and unloading, more than 3 hr. per day. A horse-drawn vehicle can meet all such requirements. Truck capacity has been created by the manufacturers that cannot be utilized because of the conditions under which the trucks operate.

Terminal Expense

Line hauls by railroads, declared Major Church, are very cheap. The largest part of the expense of shipping goods lies in getting the goods to and from the railroad stations. In many instances, the actual cost is from 10 to 16 times the amount paid to the railroad for the line haul.

By way of illustration, Major Church told of a case in which the cost of trucking goods uptown from 46th Street and the Hudson River was more than that of bringing them 3000 miles across the Atlantic Ocean, including the insurance; and of another case in which the cost of two truckings of a shipment of powdered milk through the streets of Brooklyn exceeded the cost of sending the goods from New York City to San Francisco by way of the Panama Canal. Congestion, he said, entails a loss in New York City alone of more than $500,000 a day.

Failure of trucks to render full service has four principal underlying causes: (*a*) general underloading, (*b*) traveling unnecessary distances because many of the freight stations are badly located, (*c*) suffering of delays because of inadequate terminals and street congestion and (*d*) necessary traveling at very slow speed. Amplifying these points, Major Church said that trucks were usually underloaded because they carry only the amount of freight that is destined for a single station, for only one delivery can be made in an afternoon. By having unified terminals, similar to union passenger-stations, the loading could be increased. The stations would then act as clearing-houses for sorting the freight. As Manhattan alone does the business of 10 ordinary cities, if it were split up into districts, each handling an equivalent amount of freight, and a union station were placed at the center of each district, the distance that the freight must be hauled would be reduced.

Delays at Stations

A record kept at one of the railroad pier stations for a week, to determine the time consumed in loading and unloading trucks, showed the average time to be 68 min. The average time required to unload was 14 min. The waste was therefore 54 min. which, at a cost of $0.06 per min., meant a loss of $3.24 per load. The loads averaged only 2154 lb. The freight, he declared, could be hauled from New York City to Buffalo by rail for the same expense.

On long hauls, the average distance covered by a truck is about 47.7 miles. Trucks are encroaching upon the long-distance hauling by the railroads because of the saving in the handling operations at each end. To support this statement, Major Church cited the case of a shoe manufacturer in Massachusetts who found that a saving in the cost of boxing, carting, and the like, amounting to $11 per ton or $66 per trip could be effected by shipping his goods by truck. This more than offset the difference between the costs of the line hauls of the motor truck and the railroad. Similarly, a well-known typewriter manufacturer saves $1 per typewriter or $300 per load in the boxing alone, in shipping typewriters by motor truck from Hartford, Conn., to New York City.

Future Developments

Looking into the future, Major Church predicted the construction and use of special motor trunk-line highways, trunk-line belt-lines around the centers of congestion and special developments for bringing motor trucks to the waterfront. On the trunk lines he pictured tractors drawing trailers controlled by airbrake equipment over roads laid out with regard to grades and curves with the same care that is exercised in the construction of a railroad bed; with facilities in the way of lights, telephones, and wrecking service; and a dispatching department for handling the traffic as intensively as it was handled in France during the war. Along the trunk highways, he said, a new development in cities would be found and, with the distribution of electric power, home industries would spring up.

Motor trunk-lines, declared Major Church, would undoubtedly be built and paid for in the same manner that the original highways were built, that is, by farmers and those particularly interested, a toll being charged others for the use of them.

The question as to how space for such main highways could be obtained was answered by the suggestion that the railroad rights-of-way be used. These, being of the proper width and having easy curves and low grades, might be double-decked. The railroads' approval, Major Church believed, could be readily obtained, for such utilization of their properties would help them carry their burdens of taxation.

STEAM-COOLING AND OIL-DILUTION

A. Ludlow Clayden Explains Their Relation at Meeting of Indiana Section

A. L. Clayden

Steam-cooling, particularly with regard to its effect on lubrication and upon the dilution of gasoline with oil at the higher engine temperatures, engaged the attention of the Indiana Section, at its first regular monthly meeting of the fall season, held at Indianapolis, on Oct. 8. A. Ludlow Clayden, chief engineer of gas-engine research of the Sun Oil Co., having previously presented two papers on similar subjects, spoke extemporaneously, covering much of the ground already reported in earlier issues of The Journal.[1]

Explaining that his only interest in steam-cooling was in connection with its effect on lubrication, Mr. Clayden added that the more he investigated the system, the more did it appeal to him as having many advantages. Steam-cooling, continued Mr. Clayden, is a comparatively old idea. Some of the earliest gasoline engines have been and still are steam-cooled, although the present method of steam-cooling is comparatively modern. Much of the misunderstanding of the subject, he believes, is caused by its name. The steam, however, actually does the cooling, the latent heat of water instead of its specific heat being utilized in the process. The main function of the steam-cooling system is to keep the cylinder jacket full of water; the water may be above the boiling temperature but the cylinder must be kept cool.

An interesting feature of the steam-cooling system, he said, is the great rapidity with which it reaches operating temperature. The jacket water is not subjected to any radiator cooling until it boils, but its rise in temperature to this point requires only a few minutes. The general method of operation of a steam-cooling system was outlined and the effect of the increase of cylinder temperature on oil dilution was explained.

PRESENT-DAY AUTOMOTIVE FUEL

Processes of oil refinement were exhibited and described to the 40 members and guests of the New England Section who visited the plant of the Beacon Oil Co., at Everett, Mass.,

(*Concluded on p.* 436)

[1] See The Journal, July, 1924, p. 47, and July, 1925, p. 58.

Reliability As a Factor in Air-Transportation Efficiency

By J. PARKER VAN ZANDT[1]

AERONAUTIC MEETING PAPER *Illustrated with* CHARTS

ABSTRACT

THE user of transportation service has a very simple way of measuring its efficiency, that is, in terms of its practical value to himself. The five principal factors that determine this value are reliability, safety, rapidity, cost and availability. When the user has a choice of two different means of transportation over a given route, it is the *relative* standards of the two services that are of most interest to him, not the *absolute* values of these factors. This relation, expressed algebraically, may be called the fundamental equation of transportation efficiency.

The factor of relative reliability in this equation is isolated for discussion and its value is determined for rail and air transportation over the New York-to-Chicago route. The average on-time regularity of passenger trains is shown to vary from 74 per cent in February to 88 per cent in May, with an annual average of 81 per cent. These figures are for New York State trains and are shown to be also reasonably representative for the fast trains between New York and Chicago.

The average on-time regularity maintained by the Air Mail over the same route for a 2-year period is shown for a number of schedules based on different ground-speeds. For a ground-speed of 70 m.p.h., or about 25 m.p.h. less than the present planes' cruising-speed in still air, the on-time performance varies from 73 per cent during the winter to 98 per cent during the summer, or an annual average of 85.8 per cent. Hence, on a properly chosen time-schedule, aircraft can now be operated with a better on-time performance than trains can be operated.

A schedule approximately 25 m.p.h. slower than the cruising speed of the airplanes must be chosen in order to take proper account of the frequency and strength of opposing winds. By failure to make this allowance in its announced schedule for the New York-to-Chicago overnight service, the Air Mail Service is inviting discredit to itself and operates to obscure the true dependable qualities of air transportation. In fairness to itself and to the public, the Air Mail Service should base this schedule on a ground-speed at least 15 m.p.h. slower than the schedule announced or new aircraft should be employed that have a cruising speed at least 15 m.p.h. greater than the planes at present in use in the service.

A USER of transportation has a very simple way of measuring its efficiency; that is, in terms of its practical value to himself. If the principal factors that determine this value for the user are analyzed, it is found that there are five: reliability, safety, rapidity, cost and availability. If we wish to establish an air-transportation service over a given route, we are interested not so much in *absolute* standards of the factors named as in the *relative* standards of the proposed service as compared with the quality of transportation service already available over the same route. Expressing this algebraically, we have the following equation, which may be called the fundamental equation of transportation efficiency:

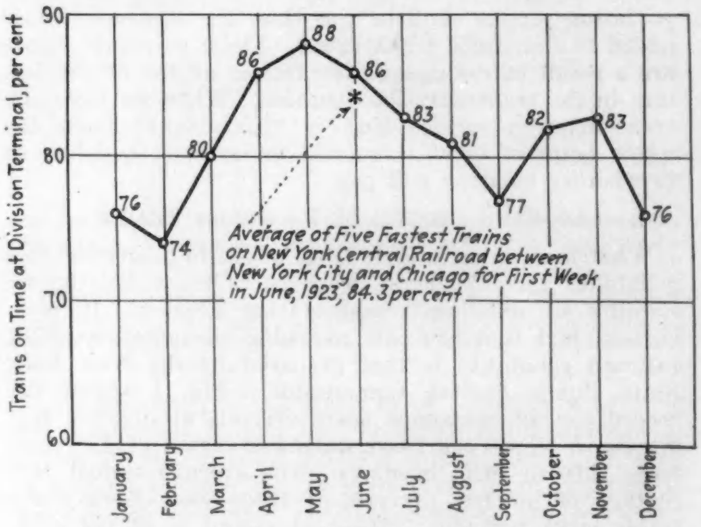


FIG. 1—AVERAGE RELIABILITY OF PASSENGER TRAINS

The Curve Shows the Average Percentage by Months of Passenger Trains Arriving on Time at Division Terminals in New York State during the 11 Years from 1910 to 1920, Inclusive. The Number of Trains Reported Each Month Is between 60,000 and 70,000, and the Average Reliability for the Entire Period Is 81 Per Cent. Note That the Greatest Regularity Is in April, May and June, and That the Average On-Time Arrivals of the Five Fastest New York Central Trains between New York City and Chicago, as Made Public by the Railroad Company, Is 84.3 Per Cent in June, Which Fairly Corresponds with the Average for That Month of All Trains in New York State as Reported by the Commission

$$\text{Air Transportation Efficiency} = f\,(r, s, t, c, a)$$

where

r = relative reliability with respect to existing transportation facilities over the same route
s = relative safety
t = relative time in transit
c = relative cost to the user
a = relative availability, or convenience of using

No one of these factors can properly be considered alone. A service with well-nigh perfect reliability and safety might still be of little interest to the user if it were too infrequent or were available only at the wrong hours. From the operator's point of view as well, each of these factors reacts on the others. A compromise in reliability might be permitted, for example, in order to increase the rapidity of the service or to decrease the cost to the consumer. Nevertheless, it will be of interest to attempt to isolate the reliability factor for the moment and to consider where we stand today in air transportation as regards this one factor alone. Suppose we let

Ro = reliability of existing transportation service over a given route

[1] S.M.S.A.E.—Secretary of the committee on civil aviation, Department of Commerce, City of Washington.

R = reliability of air transportation over the same route

Then

$R/Ro = r$ = relative reliability of air transportation with respect to existing standards for that route

If the airline is less reliable, then $r < 1$

If the airline is "just as good", then $r = 1$

If the airline is more reliable, then $r > 1$

Of course, r may be <1 and still be satisfactory. That is, the other four factors affecting the overall efficiency of the service may more than make up for a deficiency in the reliability factor. As an economist would say, all that is required, from the consumer's and the operator's points of view, is that the cost of supplying the transportation service shall be less than the economic values added to the traffic transported. These economic values are a result of the composite effect of all five of the factors in the transportation equation. When we have air-transportation service that is "just right" from the users' point of view, there will be no more question as to whether aviation will pay.

On-Time Records of Passenger Trains

What facts are available from which to determine this reliability factor? First, we need to know Ro, the reliability of existing transportation service. It is a curious fact that the only available adequate record of railroad reliability is that prepared by the New York State Public Service Commission. Fig. 1 shows the record for all passenger train arrivals at division terminals in New York State during a period of 11 years, from 1910 to 1920, inclusive. The average annual percentage of on-time arrivals of these New York State trains is 81 per cent. The best record is 88 per cent, made during May; the poorest is 74 per cent, made during February. Each monthly percentage represents an average of about 700,000 train-trips reported. Trains less than 5 min. late are reported as "on-time."

I have made an effort to determine the percentage of on-time arrivals of limited trains between New York and Chicago at their destinations but, unfortunately, the railroad companies are not so proud of these figures that they are willing to make them public. A certain amount of information is at hand, however, which will serve to indicate whether the figures for New York State may be taken as a fair measure of the reliability of extra-fare trains. The on-time performance of the three limited

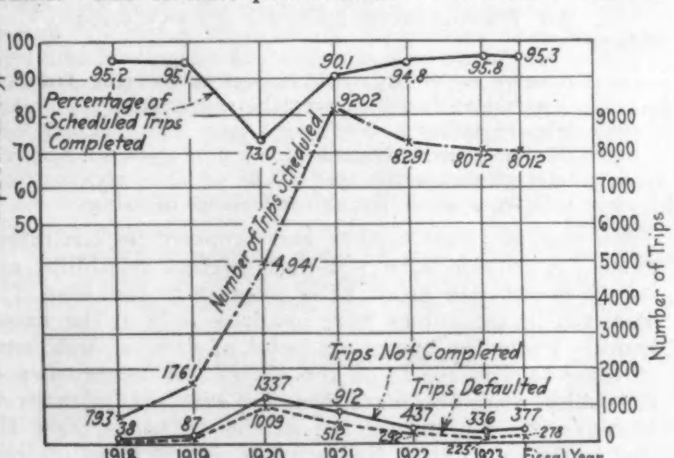


Fig. 2—Air Mail Service Reliability Records

This Chart Covers the 6 Years of Operation from the Inauguration of the Service in 1918 to the Establishment of the Night-Flying Schedule in 1924. The Big Drop in 1920 Was Due to Uncompleted Trips on the Omaha-to-San Francisco Portion of the Transcontinental Route, over Which Service Was Started on Sept. 8 of That Year. The Slight Drop in the Early Part of 1924 Probably Is the Result of Voluntary Sacrifice of the Reliability Factor To Increase the Safety Factor

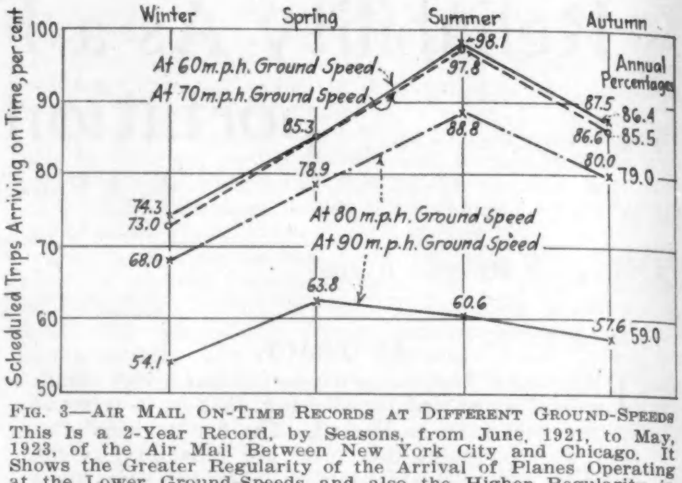


Fig. 3—Air Mail On-Time Records at Different Ground-Speeds

This Is a 2-Year Record, by Seasons, from June, 1921, to May, 1923, of the Air Mail Between New York City and Chicago. It Shows the Greater Regularity of the Arrival of Planes Operating at the Lower Ground-Speeds and also the Higher Regularity in Summer at the Lower Speeds and in the Spring at the Highest Speed. Data for These Curves Were Taken Directly from the Logbooks of the Planes

trains of the Pennsylvania Railroad Co. between New York and Chicago, for the month of May, 1923, was as follows:

Trains operated, both directions, total	190
Trains arriving at destination on time, total	169
Per cent of trains on time	89

The three trains referred to are those having a schedule time of 20, 22 and 23 hr., respectively, each way.

The on-time performance of the five fastest trains of the New York Central Railroad between New York and Chicago, for the first week in June, 1923, was as follows:

Trains operated, both directions, total	70
Trains arriving at destination on time, total	59
Per cent of trains on time	84.3

The New York Central trains referred to are:

Westbound—	No. 1	The Mohawk
	No. 3	Chicago Express
	No. 17	The Wolverine
	No. 19	Lake Shore Limited
	No. 25	Twentieth Century Limited
Eastbound—	No. 6	Fifth Avenue Special
	No. 8	The Wolverine
	No. 22	Lake Shore Limited
	No. 26	Twentieth Century Limited
	No. 40	Michigan Central Limited

Without malice in this connection, I should like to point out that the figures made public by these two railroad companies are chosen from May and June, the particular months in which their services are least subject to interruption, as revealed in Fig. 1. The data for these limited trains check closely enough with those of the New York State Public Service Commission to indicate that the record of the Commission may be accepted as a fair average measure of present railroad reliability.

Remarkable Reliability of Air Mail Service

Can air transportation, in its present state of development, operate with an annual on-time performance of 81 per cent? If it can, its present standard of reliability must be accepted as on a par with existing train standards. An answer to this question is to be found in the records of the Air Mail Service of the Postoffice Department. A graphical picture of the general character of the Air Mail performance is presented in Fig. 2, which shows the Air Mail record from its inauguration up to the beginning of regular night-flying. The average length of an Air Mail trip is approximately 200 miles; thus, for the fiscal year 1924, the planes flew a total of

1,522,763 miles, with mail, in a total of 7635 completed trips. The service evidently has shown steady improvement in its performance from 1920 to 1924. The drop in 1920 is due to uncompleted trips on the Omaha-to-San Francisco part of the route, over which service was begun Sept. 20, that year. The slight decrease during the first 6 months of 1924 probably is the result of a voluntary sacrifice in the reliability factor in order to increase the safety factor.

When it is recalled that this is a record of a pioneer venture groping its way in an unknown field, Fig. 2 reveals a truly remarkable performance. It does not, however, give us the information we need for comparing the service with the railroad reliability record. It is necessary to know the per cent of all scheduled trips that were completed *on time*, according to some fixed schedule. Fig. 3 presents this information for the New York-to-Chicago portion of the transcontinental route, for four different time-limits, from 60-m.p.h. to 90-m.p.h. ground-speed.

How Prevailing Winds Affect Regularity

The data on which these curves are based have been taken directly from the log-books of the planes. Those who may be interested in the detailed statistics will find them in an article on The Frequency of Winds[2]. The normal cruising-speed of the Air Mail DeHaviland planes was there shown to be 96.5 m.p.h. Thus it is seen that, if an attempt is made to maintain a schedule based on a ground-speed approximating the cruising-speed of the planes in still air, the regularity of the service falls far below train regularity, but, if an allowance of 25 m.p.h. or more is included as margin between the ground-speed upon which the schedule is based and the planes' cruising-speed, the regularity of the service rises to 85 per cent or better.

That the primary reason for the failure to arrive on

[2] See *Monthly Weather Review*, March, 1924, p. 154.

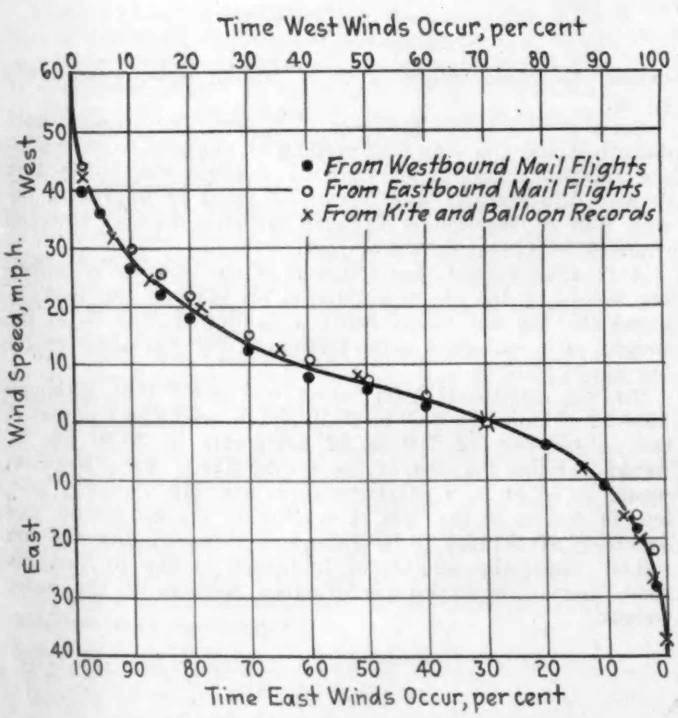


Fig. 4—Persistence and Strength of West and East Winds
The Records Show That West Winds Blow a Greater Percentage of the Time and Are of Greater Strength than the East Winds. West Winds of 25 M.P.H. or More Blow 15 Per Cent of the Time and Are the Primary Reason for Failure of the Mail Planes to Arrive on Time More Often

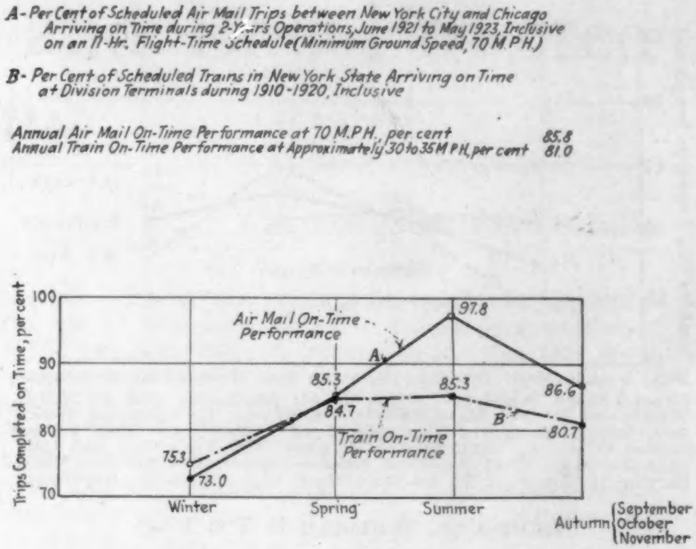


Fig. 5—Relative Reliability of Air and Rail Transportation
Based on a Ground-Speed Schedule of 70 M.P.H., the Mail Planes Show On-Time Averages Ranging from 73 Per Cent in Winter to 97.8 Per Cent in Summer during a 2-Year Period. Passenger Trains Operating on a Schedule Half as Fast Show Averages Ranging from 75.3 to 85.3 Per Cent. This Comparison Furnishes Proof That, on a Conservative Time-Schedule, a Well-Organized Service Can Give Greater Regularity of Service than Passenger Trains

time more often is the strength of opposing winds and not mechanical trouble or impossible flying-weather, is shown by Fig. 4, from which it will be noted that westerly winds of 25 m.p.h. or more occur approximately 15 per cent of the time. A comparison of the two lower curves of Fig. 3 reveals the interesting fact that, for a schedule based on a ground-speed of 90 m.p.h., an increase of about 10 m.p.h. in the present cruising-speed would raise the resultant on-time performance for that schedule by approximately 20 per cent.

Planes Are More Reliable Than Trains

We may now compare any one of the curves in Fig. 3 with the on-time performance of railroad trains, as shown in Fig. 1, to obtain a measure of the relative reliability of the two forms of transportation. It is only fair to select a schedule for the aircraft that makes a proper allowance for the frequency and the strength of opposing winds; that is, for the present Air Mail planes, we should choose a schedule based on a ground-speed of approximately 70 m.p.h. Fig. 5 presents this comparison; namely, the on-time performance actually attained by the Air Mail between New York and Chicago during the 2 years and the railroad on-time performance at a speed relatively one-half as great.

Here we have experimental proof that when a conservative time-schedule for a well-organized air-transportation service is chosen, a guarantee can be given that the planes will arrive at their destinations on time with a degree of regularity greater than present-day train regularity. This record is all the more remarkable for having been made without the aid of radio direction-finding, with an inadequate weather-reporting service, and with equipment, instruments, and route-organization far below the standards of efficiency to which we know they can be brought. When it is remembered that railroads have been operating for more than 80 years, while air transportation is barely 5 years old, this performance becomes still more impressive and reflects unbounded credit on the men in the Air Mail Service who have made it possible.

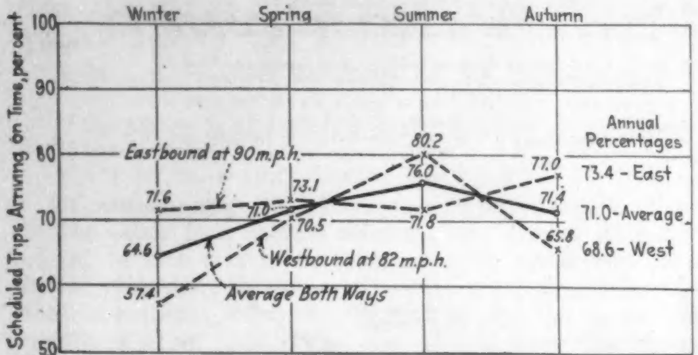


FIG. 6—AIR MAIL ON-TIME RECORDS FOR HIGH-SPEED SCHEDULES

Ground-Speed Schedules of 90 M.P.H. Eastbound and 82 M.P.H Westbound Do Not Make Sufficient Allowance for Opposing Winds and Result in Lower Percentages of Reliability. This 2-Year Record of the Air Mail Service Between New York City and Chicago Indicates That the New Schedule Announced for the Night Service Is Too Fast To Be Maintained with Creditable Regularity

NIGHT-MAIL SCHEDULE IS TOO FAST

I hope I shall not be misunderstood if I close with a warning. In its latest announced schedule for the New York-to-Chicago night service, it appears, in the light of the foregoing facts, that the Air Mail is inviting discredit, not only to itself, but to air transportation in general. It has neglected to be guided by its own experience and has placed itself under obligation to meet a schedule which, with its present flying equipment, it cannot maintain with a degree or regularity approaching present railroad standards. In short, the published schedule does not make adequate allowance for the normal delays that experience shows will inevitably be encountered in regular day-in and day-out operation of a commercial air-transportation line.

The Postmaster General, in his testimony before the President's Aviation Board on Sept. 23, 1925, stated that the westbound trip over the New York-to-Chicago night-flying route "is scheduled to be made in 9 hr. 15 min. This time includes stops at three stations for service and the exchange of mails. Only 8 hr. 30 min. are used in the eastbound trip." The distance flown is 726 miles. If we allow, as a minimum, an average delay of 10 min. for service and the exchange of mails at each of the three stops, there are left only 8 hr. 45 min. in which to fly the 726 miles westbound and 8 hr. for the return trip eastward. This is equivalent to a scheduled ground-speed of 83 m.p.h. westbound and 90.8 m.p.h. eastbound. Fig. 6 indicates the regularity that the Postoffice Department may expect to maintain with such ground-speeds, using the present flying equipment and assuming, further, that night-flying operations will be fully as reliable as the best records for daytime flying over this same route.

In fairness to itself, the Air Mail Service should base its schedule on a ground-speed at least 15 m.p.h. slower or employ for the service aircraft having a cruising-speed at least 15 m.p.h. faster. Only by so doing can it hope to avoid future criticism on the score of insufficient reliability. For its own sake and in the interest of educating the public to the true merits of air transportation, the Air Mail Service should profit by its own experience and put its best foot forward.

MEETINGS OF THE SOCIETY

(*Concluded from p.* 432)

prior to the Section dinner and meeting held on the evening of Oct. 26 at the Engineer's Club, Boston. The attendance at the dinner was 35, that at the meeting being 50.

Two informative papers were presented at the meeting by representatives of the oil company, the one on the Cracking of Oil for Fuel being by L. J. Walsh, assistant general manager, and that on Motor Fuel being by R. J. Lybeck, chemical engineer. A spirited discussion followed their delivery. It is expected that publication of the papers will be made in a later issue of THE JOURNAL.

PHILOSOPHY OF WEIGHT REDUCTION

L. H. Pomeroy Tells Buffalo Section of Possibilities Through Use of Aluminum

In discussing the Philosophy of Weight Reduction before the Buffalo Section, at its regular monthly meeting on Oct. 13, L. H. Pomeroy, of the American Body Co., Buffalo, first referred to the "vicious cycle" previously prevailing of adding weight to strengthen parts, of increasing the power to utilize the added weight, then of adding more weight, and so on.

Some of the newer methods of determining stresses were described and the soap-film method of analysis to determine the relative torsional strength of sections was outlined in detail. Illustrations were shown of ways of improving design and of increasing strength without making material changes or increasing the weight.

A detailed explanation followed of the manner of reducing weight by the use of aluminum for various unit parts of a vehicle, the net result being a saving of 700 lb. in the weight of a full-sized seven-passenger car normally weighing about 3500 lb.

But the additional information was given that, although 1400 lb. of iron and steel at $0.10 per lb. would be eliminated, the substitution of 700 lb. of aluminum at $0.40 per lb. would increase the cost of the car by $140. This, however, would be offset to a considerable extent, Mr. Pomeroy said, by the saving in the cost of machining the aluminum, and by other advantages to be gained in riding-quality through lighter unsprung weight, in increased ability to hold the road, and in improved performance because of the lesser weight.

The Light Airplane and Low-Powered Flying

By W. L. LePage[1]

Aeronautic Meeting Paper

ABSTRACT

As the application of aviation to commercial and private needs increases, economy of operation becomes more important. During the war, maximum performance was the objective sought and cost of operation was not considered; progress in performance was made rather by increasing the power of the engine than the efficiency of the design. Although airplanes have reached a high state of perfection in some respects, their failure as commercial carriers has been due to the cost of the up-keep and operation of the necessarily high-powered engines.

Airplanes coming under the category of light machines are of great importance because they represent the thin edge of the wedge in the development of lower-powered and more economically operated freight and passenger-carrying air-liners.

Formerly, little knowledge of the theory of air-foils was available and the idea of operating with a throttled engine, even though the airplane were in full flight, was unheard of. Development of true low-powered airplanes began with the production of the Wren in 1923 and as a result of the data obtained from the English, French and German gliders about that time the possibility of controlled flight with an engine of only 398-cc. (24.288-cu. in.) cylinder-capacity was determined.

The Dayton races showed that the popularization of the light airplane called for more reliability, lower initial cost and up-keep; and handiness of operation, which means low landing-speed and quick climb.

Various features that enter into the successful operation of the light airplane are considered by the author and their relation to those of airplanes of larger size is discussed. These include such topics as reduction of the over-all size, the percentage of the weight carried to the total load, problems of control and the proportions of the control surfaces, the expression of these areas in terms of wing-area, the amount of control surface required for longitudinal stability, the importance of high aspect-ratio in producing effective control, the relation of engine size to weight, together with the fuel-load, the requirements of a satisfactory light-weight aircraft-engine, and the advantages to be gained from the use of superchargers.

Among the ultimate uses and applications to be made of the development of the light airplane are cited the significance of the features and principles derived from the operation of the machines, their value in the designing of larger and more powerful airplanes, and the development of economical flight by lowering the power required and increasing the percentage of useful load. By enabling designers to test new designs by diminutive replicas in model form and to obtain from them sufficient information regarding new principles of design, these principles can then be embodied in larger machines with confidence.

With the constant trend of thought in the development of aviation being directed toward the application of this comparatively new art to commercial and private needs as opposed to military purposes, the cry for economy in operation is ever becoming stronger. One of the greatest drawbacks to the extensive use of the airplane as a regular transportation vehicle has been the cost of operation. For this state, we have very largely the war to thank. Reference is made to this period because it was in the 4 years from 1914 to 1918 that such very great strides were made in the development of aeronautics; yet it was in that same period that development was initiated along lines which, from many standpoints, have spelt slow progress for the ensuing years.

In the war period, the maximum performance of airplanes was at a premium and the cost of operation did not enter into the equation. Consequently, we find progress in performance going on apace; but a closer review of the facts tends to show that this performance has been gained far more from the incorporation of more power into the designs than from true efficiency. And the results have been inevitable.

Aeronautic design, having reached a high state of perfection, was, nevertheless, at the conclusion of hostilities, totally unable to provide airplanes capable of being of real commercial value as express-carriers; and this was owing to one thing; the cost of up-keep and operation, largely because of the high-powered engines necessary, was far beyond the possibility of any commercial gain. The service has long been needed but the cost has been too high.

For this reason the class of airplane coming under the category of the light machine is of such very great importance at this time. Not that it, of itself, is of such vast significance, but because it represents the thin end of the wedge in the development of lower-powered and more economically operated freight and passenger-carrying air-liners.

Comparison of Present and Previous Performances

When attention is directed toward the development of the modern low-powered airplane, it is of peculiar interest to recall the performances set up by the low-powered flying-machines of 15 and 20 years ago. The maximum and minimum speeds of these early craft were never separated by more than a few miles per hour, the climb was extremely small, and the ceiling but a few hundred feet. Control was poor and it would take a skilful modern pilot to make a real success of a flight in one of them.

It was always necessary to get the very last ounce of power out of the engines with which these early airplanes were fitted out, although this applies to a certain extent to the modern light machine, the idea of a throttled engine, even though the airplane were in full flight, was unheard of. But the early designs, although of very low power, could be classed with those of the modern low-powered airplane, for it is certain that, had an engine developing more than 12 or 14 hp. and at the same time light in weight, been available, the Wrights would have used it for their airplane, which in modern times would be considered vastly under-powered. The great differ-

[1] Jun. S.A.E.—Editor of *Aviation*, New York City.

ence may be seen from an insight into the technical details involved in the design of the early airplanes.

Knowledge of Theory of Airfoils Lacking

In the first place, no knowledge of the theory of airfoils existed as it is understood today, and, consequently, the wing-sections of these early machines rendered large lifting-surfaces necessary, which, owing to the poor lift drag ratio, brought the aerodynamic efficiency of the whole design down low. The large surfaces made necessary extensive structural arrangements that spelt higher parasite drag and lowered the over-all L/D ratio farther.

It is extremely doubtful whether even as much as 50-per cent efficiency could be obtained from the air-screws designed for those early craft, but I am not aware of the actual figures in this respect and would welcome reliable data. It is easy, however, to see how, with everything piled up against them, those pioneers had enormous problems to face in producing airplanes with even the comparatively meager performances then obtained. It is not proposed to belabor this aspect of the subject unnecessarily, but it is contended that only by a thorough understanding of the reasons behind the comparative shortcomings of the early designers will a real perspective view of present-day development in this field be obtained.

With the backing of modern advanced theory and experience, the development of airplanes capable of really high performance on very low power, that is, true low-powered airplanes, began with the production of the Wren light airplane in 1923. As a result of the data obtained from the English, French and German gliders that had been flying and making records about that time, it was determined, after a preliminary investigation, that it would be possible to build an airplane along the lines of a glider that would fly with an Allen Bennett Croydon motorcycle engine of only 398-cc. (24.288-cu. in.) cylinder displacement. In fact, according to calculations, this airplane showed the possibility of flying level with the remarkably low power of 3.5 hp.

Predictions Fulfilled by the Wren

It is probably well known now, how closely these predictions were fulfilled in the Wren, and, in fact, how all expectations were surpassed. This design showed the possibility of controlled flight with an engine of only 398-cc. (24.288-cu. in.) cylinder-capacity and carrying a pilot and 2-hr. fuel supply on protracted flights. It showed that a speed-range of from 23 to 50 m.p.h. could be obtained and that the possibility of climbing 200 ft. per min. was an actual fact. It further developed, and this was most significant, that a small-diameter high-speed ungeared air-screw is not very inefficient.

These conditions have not ultimately proved sufficient for reliable flight under all weather-conditions. The extremely light wing-loadings of necessity set up serious difficulties of control. A wing-loading of 2.5 lb. per sq. ft. is not small, when it is compared with that of pioneer airplanes, which were considered, as regards control, at least tolerable in those days; but the conditions of better speed-performance in the modern design necessitate details of design that, under these conditions, impede the control characteristics.

Although the extremely fine characteristics of the early modern light airplanes of 1923 were demonstrative of their great possibilities, their poor comparative climb was one indication of the need of greater power. Modern light planes are flying with power-loadings of from 30 to 35 lb. per hp. and in some cases as much as 60 lb. per hp. Furthermore, an L/D ratio of 14 is common, compared with 5 or 8 in commercial and military types. Engines, however, can only be considered to be greatly overloaded; consequently, it is my firm conviction that these types cannot be developed for real service without more horsepower. It is proposed to take up the power question at greater length later.

Light Airplanes Develop Reliability

The great point to be decided, in discussing this totally unstable development of modern aeronautics is, Just what are we aiming to reach? The mere construction of small airplanes with tiny engines, and the accepting of their many shortcomings, will not bring out the enormous possibilities to be derived from a carefully guided development of this particular trend.

It became fairly apparent and was voiced frequently, after the light airplane races held in conjunction with the International Air Races at Dayton last year, that the popularization of the light airplane called for more reliability, a matter that was proved to be solely dependent upon the engine; lower initial cost and up-keep; and handiness of operation, which, of course, means low landing-speed and quick climb, rendering the negotiation of average fields feasible.

Extensive reductions in over-all size are definitely limited, unless wings of considerably greater optimum lift-coefficient are employed; and this would conflict with the necessity for a high value of L/D, bearing in mind that the effective speed-range of the biplane had first to be cut, as would be the case if an inefficient wing-section were employed. Low initial-cost of the airplane was included in the estimate, because this detail is so closely linked with structural design as to be almost directly proportional to it, and likewise needs no special comment by itself.

Structural Design

Structural design of airplanes of the low-powered class is extremely important in view of their high percentage weight. It has been found impossible in many cases to cut this below 44 per cent, as compared with approximately 33 per cent for larger airplanes of the same factor of safety. Consequently, although it is believed that little can really be gained in this respect, for it is the low engine-weight in the light airplane and the absence of many additional features, such as elaborate instruments, forming part of the standard equipment of the normal airplane, that tend to raise the percentage of its structural weight, it is, nevertheless, most important that structural design be given the closest attention.

It has been noticed, however, in a survey of a series of recent designs, that the average loads carried in light airplanes amount to from 36 to 42 per cent of the total weight of the airplane as against from 25 to 30 per cent for normal large aircraft. Some of this difference may, of course, be accounted for by the small quantities of gasoline and oil usually carried in the light airplanes.

In the design of a successful light airplane, the most serious problems of all, however, are those of control. Ordinary rules of proportioning control-surfaces appear to break-down entirely, probably as a result of the low wing-loading characteristics. The discrepancies have always been on the low side and any fault in the design of the control-surfaces has been that of too little area. The probable causes of trouble from this source may, however, be traced farther. Frequently, the form and section of the control-surfaces have been such as to render the flaps inefficient.

Another cause of trouble has been the blanketing effect of the fuselage, causing trouble largely with the rudder control. With the comparatively slow slip-stream velocity of small airplanes, any further slowing-up of the air passing by the tail will, of necessity, be responsible for very inadequate rudder-control and longitudinal control with the elevators.

Further trouble is caused by distortions of the structure itself. I have observed a case in which the wings of a light airplane, although very beautifully constructed, were by no means rigid enough under torsion, with the result that the depression of an aileron during flight produced an opposite flexure of the wing-tip that not only caused a loss of the desired lateral control, but, under certain circumstances, actually reversed this control.

Control-Areas Defined in Terms of Wing-Area

Turning first to areas and neglecting for the moment other modifying factors, if it can be assured that the structure will remain rigid and that no undue aerodynamic interferences must be considered, the correct control-areas should be possible of definition in terms of wing-area.

In a normal design of a light airplane, in which the general plan-form is similar to that of the usual practice in larger designs, and with a wing-loading of the order of 5 or 6 lb. per sq. ft., a tail area, including elevator flaps, of approximately 10 per cent is suggested as suitable, whereas, if the wing-loading is extremely light, this percentage should be considerably increased, even to 18 per cent. It should be remembered, however, that it is impossible to lay down hard and fast rules in this respect, since a change in the length of the fuselage would entirely alter the required tail-areas.

Rudder and fin area is, of course, dependent upon the design of the fuselage and the dihedral angle, if any, of the main planes; in fact, upon the total finnage of the entire design. It can, however, be said with fair safety that the rudder-area should be much larger than that considered adequate in most designs. It is advisable, furthermore, to remember the close connection between the aspect-ratio and the percentage of control-surface areas, referring in this case to the total area of all the tail surfaces and not merely to the movable portions. When the aspect-ratio is low, an increase in both the horizontal and the vertical stabilizer areas is advisable, a fact that has at this time become very generally established in practice.

The amount of control-surface necessary is, of course, closely associated with the degree of longitudinal stability required in the design. This is largely owing to the fact that, in general, the longitudinal stability increases as the center of gravity moves forward; and this movement of the center of gravity, as has already been pointed out, is closely interconnected with the areas of the tail surfaces.

High Aspect-Ratio Desirable

Regarding the previous mention that has been made of the importance of the general form of the control-surfaces, reference was made to the now well-known fact that aspect-ratio is extremely important in its bearing upon the effectiveness of control flaps and, consequently, should be made as high as possible. The ratio of the over-all span of the horizontal tail-surfaces to the combined chord of the stabilizer and the elevator should be at least 2, and a higher value is even more satisfactory; likewise, this is the case with ailerons, in which the effects of aspect-ratio are extremely noticeable and have been proved by wind-tunnel experiments to be most important.

Passing to the consideration of engine-power in the light airplane, a question that, by hypothesis, is of primary importance, the greatest diversity of opinion is to be found. The importance of a thorough agreement on this part of the problem cannot be overemphasized, for it is at the very root of the light-airplane question. Being of such importance, engine power was the first and the major stipulation in the contests that have been organized, both in this Country and abroad, for the development of low-powered flying. Engine power is based primarily upon cylinder capacity, although some persons consider engine weight to be the feature that should be governed. Yet, over and above all, the development of the low-powered airplane surely demands economy and cheapness of first cost as a primary factor. Performance certainly is not the factor we are endeavoring to develop in preference to all else, for an average speed of from 60 to 70 m.p.h., with a maximum of 85 m.p.h., is recognized as being in general sufficiently great for this class of flying.

Relation of Engine Size and Weight

Designers must turn attention to something more than mere engine size and develop rather along the lines of the relation of engine size to weight, together with the fuel load for a given flight. In this way it will be possible to develop along wide lines for, having arbitrarily fixed a value for this relation as being representative of the general lines along which light-airplane development should unfold, an amount of leeway would remain that is destined to encourage design in several directions instead of in the one direction that has as its object the utilization of a certain category of power unit, defined within very narrow limits.

The great point to remember is that the use of a small engine of very small capacity, although undoubtedly scoring great merit with respect to aerodynamic design, does not, however, promote the production of low-powered airplanes suitable to the owner-pilot for use in private flying, where economy is of such primary importance. In fact, a consideration of engine size only may even, and undoubtedly does, tend to increase the cost both of the airplane and of the up-keep, for such an engine is, as a rule, overloaded. If, on the other hand, engine weight is considered in conjunction with fuel load, for a given period of flying, real progress will begin.

Consider, for a moment, the possible results of such a line of thought. If more power is considered necessary for a particular design, higher-class workmanship will be needed in engine production, better materials will be used, and the consumption of gasoline will be reduced, so that the relation of cylinder-capacity to fuel-consumption may remain at the previously fixed value. This will represent progress.

On the other hand, by the use of the highest grade of materials in the production of the engine and the most careful attention to its design, so that the engine weight will be decreased, and the consumption, as a result of the excellent design, will be maintained constant, more power and a better performance can be obtained from the airplane; yet this design could not be considered to be superior to the previous one, but merely as serving a different purpose and supplying a different need. The same result is obtained by both methods and each will represent progress in light-airplane design and low-powered flying.

Requirements of Satisfactory Light Aircraft-Engine

It will be readily understood, therefore, that the engine for a light airplane must not only be a low-powered and light-weight unit but, if progress is to be along the correct lines, must conform to well-defined limits that will maintain the economic and, at the same time, progressive development of economic flying. The requirements for a satisfactory light aircraft-engine are closely akin to those pertaining to the larger types, and may be classed as (*a*) reliability and (*b*) light weight when in running condition. The former requirements can be completely obtained only as a result of careful design and extensive testing, while the latter is actually more difficult to obtain in a small power-unit than in a large aircraft-engine, owing to the constructional details' not scaling in the same order.

Though it is true that a higher horsepower per unit of cylinder volume is possible in the smaller engine, certain parts, notably the cylinders themselves, must be made stouter than is indicated by the stresses set up, in order that rigidity may be provided for in the small engine. In a normal aircraft-engine this condition does not arise. Furthermore, the use of higher horsepower per unit of cylinder-capacity is strictly limited by the propeller-speed, unless, of course, gearing is introduced. This is undesirable since it has been proved, not only in low-powered but also in large aircraft-engines, to be the cause of decreased reliability and excessive vibration, unless the engine is well balanced.

Superchargers

While dwelling upon the engine section of the problem, I should like to take the opportunity to urge careful consideration of the application of the supercharger to the engines used in light airplanes. One of the primary difficulties confronted in the design of low-powered airplanes of the light-plane class is that associated with the design of the air-screw. To obtain maximum power from small engines, it has been necessary to resort to an excessive propeller-speed, which, in itself, is an inefficient condition from the standpoint of air-screw efficiency.

The use of the geared drive, as has already been stated, is a source of endless trouble, especially in small power-units in which weight is of so great importance. The suggested use of superchargers is advanced with a view to obtaining the maximum power-output from the limited cylinder-capacity, without the necessity for resorting to excessive rotational-speeds of the air-screw shaft. It should be pointed out that the suggestion is not of utilizing the supercharger principle in the manner in which it is common in aircraft at present, namely, with a view to maintaining ground-level power at high altitudes, but only of obtaining an output greater than normal for a given cylinder-capacity. The possibilities, so far as they are known, have never been given any thought and the suggestion is made here with a view to opening discussion on this point.

The great strides that have already been made in the development of the modern low-powered airplane must, of necessity, raise thoughts as to what is to be the direct outcome of this line of development and its uses and applications, if any, to the more significant and important aspects of aeronautic progress. Reference has been made to the development of the large load-carrying airplane that is to prove of such consequence in the world of commerce. In all branches of engineering practice, though details and requirements differ in the various applications, the underlying principles are applicable to all problems, and they are likewise applicable to aeronautics and airplane design. So it is that, among the problems encountered and successfully solved in the development of the light airplane, there will undoubtedly be features and principles of direct value in the design of the large and more powerful class of machine.

Minimum Power Essential for Successful Commercial Transport

It is most important that we should experiment with the minimum-power machine, not only from the purely scientific point of view and with a view to the use of such an airplane for touring purposes, but also from that of its relation to the development of the commercial aerial-transport machine. The experience gained in the development of the light airplane will be of the greatest indirect value in developing economic flight generally and, in the specific case of air-transport, in lowering the power required, enabling fuel to be carried for long-distance flights without the need of refueling in the air while, at the same time, maintaining a reasonably high percentage of useful load.

Probably the most immediate and important future for small airplanes is that suggested originally by a notable French aircraft constructor. The suggestion is to use the small airplane as a means of carrying-out actual flight-tests upon a particular new design. In effect, this means the construction of a diminutive replica of the proposed design and of flying and testing the new design in what is practically model form. An airplane of 100-ft. span, for example, would make its first appearance in the form of a one-fifth scale model having a span of only 20 ft. and built according to the general principles of light-airplane construction. In this way, costly mistakes could be largely avoided by the constructor and modifications of the design could be conveniently made and tried out at the minimum expense.

The requirements of such a flying model are fairly well-defined and are chiefly concerned with loading characteristics. It would be essential, so far as possible, to reproduce in the small airplane approximately the wing-loading characteristics expected in the final design. Likewise, the power-loading, that is, the weight per horsepower, must be maintained approximately unaltered. The real difficulty, however, will be in realizing these, as will be seen from a reference to what has already been said on the subject of structural weight in the light airplane, as compared with the figures common in normal large designs.

Conclusions

It is difficult to see how the identical aerodynamic qualities of a large machine can be reproduced under these conditions, in any useful sense, in the design of a light airplane model, but, nevertheless, these light airplanes offer a great future in being employed in aeronautic research, not as exact models for flight-testing of larger aircraft but in the testing of the principles carried out in the larger design and thus supplying sufficient information to enable a designer to embody new features in the large machine with confidence. The probability of the ultimate airplane's realizing its expected performance, unattended by the usual disappointments from falling short of such expectations that frequently result in the necessity for very costly and inconvenient modifications, so that the performance of the airplane as it stands will be endured, will be welcomed by all designers with original ideas.

Some Aspects of Airplane Inspection

By J. J. FEELEY[1]

PRODUCTION MEETING PAPER *Illustrated with* PHOTOGRAPHS

ABSTRACT

FOLLOWING a description of airplane structure, the author discusses structural requirements and outlines the main features of properly coordinating the engineering and the manufacturing activities. He says that each of the three subdivisions of airplane design has its own series of calculations, these being related to predictions of performance before the machine is built, to stability determinations and to the design of a self-contained structure of sufficient strength to withstand any stresses developed in flight or in landing. He states also that no inspection is worth the name or the money spent on it that does not include constructive work and a knowledge at all times that the intentions of the designers are being carried out in detail so that the safety of the craft is assured.

Materials used in aircraft should be light and easily workable and should possess the desired physical and chemical properties; they must have the specified cross-section and be free from defects. The methods of sampling, testing and inspecting materials are stated.

Wood structure and the kinds of wood most suitable are described, together with statements and illustrations regarding the most common defects and how they are detected, and similar explanations are made concerning the metals used.

The methods applying to fabrication, to assembling and to deterioration prevention are stated, as well as those of "doping" and finishing, and the inspection procedure for each is outlined, inclusive of that for the final assembly.

IT is not my intention to convey the impression that airplanes are difficult to build, for that is not true. They do not require a finer precision of manufacture than is required in the automotive industry; however, a multiplicity of detail is involved and no detail is so insignificant that it escapes attention. Strength and safety are two of the main considerations. Since the discussion of airplane inspection is probably new to many, I will describe the parts of an airplane, as shown in Fig. 1, and tell how they function.

The body connecting the wings with the tail surfaces is called the "fuselage." It houses the pilot and the pilot's control-mechanism, the instruments needed to inform the pilot about his direction, his altitude and how his engine is functioning, the electric-current generating apparatus and switches for its control, tools, the pilot's personal baggage and all the material carried commercially. Military airplanes, as a general rule, require more instruments and equipment than commercial airplanes carry.

The wings are placed at right angles to the fuselage, the lower one being attached directly to the fuselage structure. The upper wing is attached through a truss of struts and cables or drawn wires to the fuselage, and to the lower wing. At each outer tip of the top wing—and in some cases on both wings—is placed an aileron. The wing lifts the airplane by virtue of a negative force on its top side and a positive pressure on its bottom side, formed by its rapid motion through the air, which varies in intensity with the speed of the airplane and the curve of the wing called the "camber." The center of this pressure varies in location with the speed of the airplane and the angle at which the wing is placed in relation to the airstream. In the application of the above forces, certain drag or resistance forces have to be considered. Somewhat the same purpose is served by the ailerons attached to the outer tips of the wing as is accomplished by the "bank" on a curve in the road for a speeding automobile; they also serve to keep the airplane horizontal in the event that it is in bad alignment or encounters gusts or air pockets under a wing.

Attached to the fuselage at the rear, the tail surfaces control the directional flights of the airplane. The stabilizer is usually the larger surface. It is cambered on both sides and is designed so as to be adjustable; that is, the leading edge moves up or down and creates a lifting or a depressing force on the tail. This enables the pilot to adjust his machine to fly level and, consequently, to fly more efficiently. It also enables him to counteract any unbalanced loading condition that may exist.

To control the up and down motion, the elevators are attached to the rear or trailing edge of the stabilizer, which is cambered on both sides and, when the elevator is moved up or down, the stabilizer and elevator form a highly cambered surface which raises or lowers the tail of the airplane. When the trailing edge of the elevator coincides with the center line of the stabilizer, it is said to be neutral. The fin is set at right angles to the stabilizer and is cambered much the same. It usually is attached to the fuselage, but it can be attached to the top surface of the stabilizer. It is held in its vertical position by brace wires or cables, and by its attaching fittings.

The rudder is attached to the fin in much the same way as the elevator is attached to the stabilizer. The rudder and the fin constitute one "airfoil section" and have a very important effect on the directional stability. The rudder acts much the same in the air as does the elevator, and serves the same purpose as the rudder of a boat. The total area of the tail surfaces is about 17 to 20 per cent of the total area of the wings. This area usually is divided so that the stabilizer has 7 to 8 per cent, the elevator 5 to 6 per cent, the fin 2 to 3 per cent and the rudder 2.5 to 3.5 per cent. Fig. 2 shows the skeleton of assembled all-metal tail-surfaces.

In single-engine designs, the propeller is placed in front and mounted on the crankshaft. It is the agency employed to drag the airplane through the air. The cross-section of the propeller or air-screw is very similar to the section through the wing and decreases in thickness toward the outer end of each blade. The brake horsepower of the engine is transformed into thrust horsepower by the use of the propeller. For military airplanes the engines usually are furnished by the Army or Navy, under whose supervision many fine examples of gasoline engines have been developed.

[1] Chief Inspector, Glenn B. Martin Co., Cleveland.

Structural Requirements

Fundamentally, the problem of building an airplane is now a problem of mechanics. The engineer must know the magnitude, the direction and the point of application of all forces generated by the different airfoils and airplane movements. Airplane design can be divided into three subdivisions, each requiring its own series of calculation; briefly, they are:

(1) Predictions of performance before the machine is built, such as maximum and minimum speeds, rate of climb, maximum altitude attainable and time required, service ceiling and the like. These calculations are based on the results of wind-tunnel tests on models, the resistance of the various parts and past experience

(2) Stability calculations which determine the correct relative areas of the different components of the airplane, the angle of incidence, the length and shape of the fuselage, the position of the tail surfaces, the airfoil to be used and the relative location of the tail surfaces, to assure an inherent tendency of the machine to right itself under all conditions of flight. The center of gravity must also be determined

(3) Calculations for the design of a self-contained structure of sufficient strength to withstand any stresses which may be developed in flight, or in landing

General engineering practice concerning theories of structures and strength of materials can be applied very well to determine the stresses and size of the various parts of the structure. These are based on the magnitude and conditions of loading under the various stages of flight and landing. It is usual to design the parts of an airplane for the stresses induced, using a predetermined factor of safety or load factor. This must be large enough to cover excessive stresses and abnormal strains encountered during recovery from conditions other than those of normal flight and bad landings. It is customary to select an average factor of about six times the normal load, but this is more or less dependent on the type of machine; in fact, it varies from 4 to 20 or more in the individual parts of each machine.

Weight is a very important factor in the successful design of any machine and, in recent practice, it is customary to make the weight requirements a part of every detail and assembly drawing, allowing a certain percentage for variation, usually about 4 per cent. Fig. 3 illustrates typical all-metal airplane-construction.

Coordination of Engineering and Manufacturing

If the design of such a highly stressed mechanism as an airplane is to be successfully and safely carried out, some organization must be charged with the responsibility of meeting the engineers' intentions and with coordinating their efforts with those of the manufacturing and the repair organizations. The very nature of building airplanes calls for a capable personnel, careful for the safety provisions of the structure on which it is working. In any airplane-building organization, all errors in practice or in drawings should have the inspector's immediate attention. If he feels that he has not the necessary data, and he must know fully what the necessary data are, he should consult with the engineers who have it. I am not a believer in inspection for inspection's sake. No inspection is worth the name or the money spent on it that does not include constructive work and a knowledge at all times that the intentions of the designers are being carried out in detail so that the safety of the craft is assured. No half-way mark exists, and an inspector should be in a position to be fearless in his criticism. Inspection can be the greatest force for good and for constructive work if organized properly and handled accordingly. The inspector is constantly in touch with the manufacturing organization and, very often, is in a position to offer valuable suggestions to the designer regarding the accomplishment of shorter methods and better practice.

My remarks must not be construed to mean that inspectors are oracles who embody the essence of all knowledge. All due credit is accorded the men who make airplanes, but it is financially and otherwise impossible to hire men who invariably know when they are making an error. Many errors are made from lack of technical knowledge of the materials being handled, and of the material requirements of the structure. No place

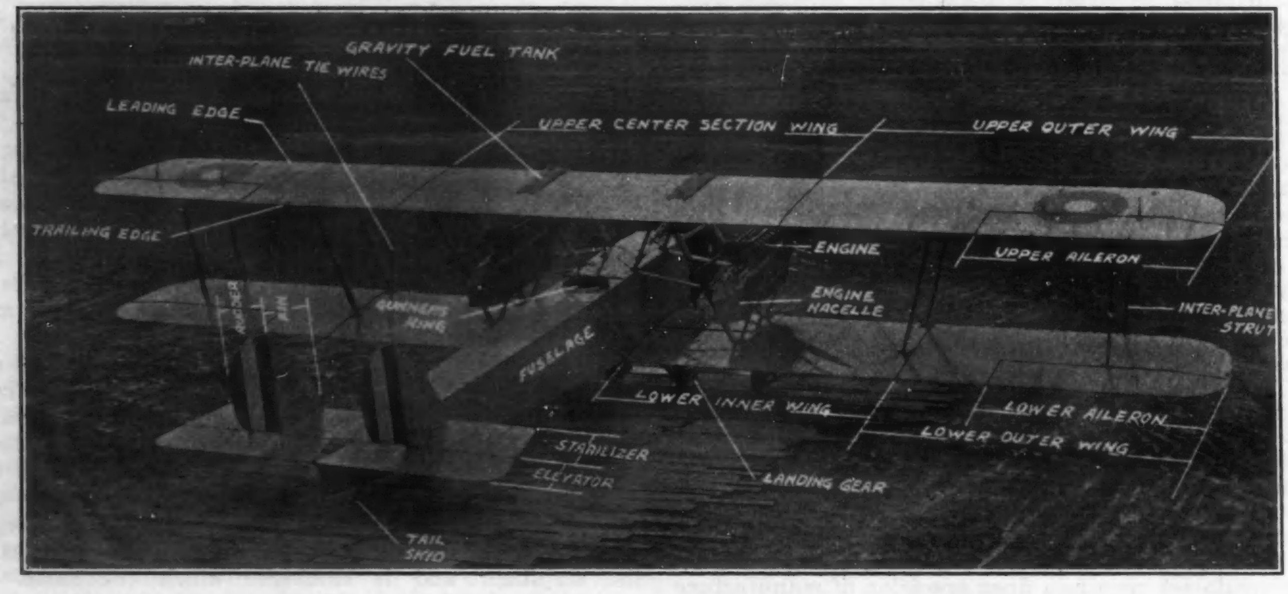


Fig. 1—A Modern Airplane
The Locations and Names of Its Most Important Parts Are Clearly Indicated

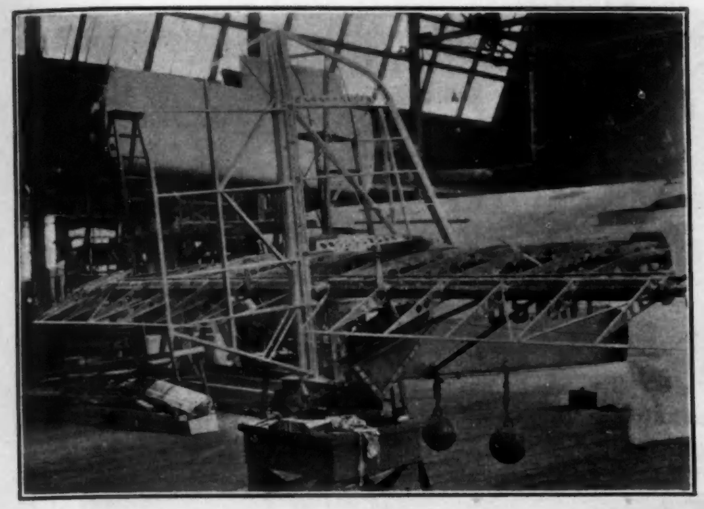


Fig. 2—All-Metal Tail-Surface Structure
The Total Area of the Tail Surfaces Is from 17 to 20 Per Cent of the Total Area of the Wings. The Skeleton of Assembled All-Metal Tail-Surfaces Is Illustrated in This View

exists for guesses and good intentions or hopes that the result will be less serious than is actually true. It is but natural that some errors be made and, errors are made. The moral is that no man should lose his standing for making an error if he exposes it, and the entire organization should be encouraged to report all errors to the properly constituted authorities. This applies to all other lines of production as well. It is absolutely too late to find an error after a failure in flight as, often, the consequence of expediency can be traced to nothing other than dead men and a pile of junk.

If commercial aeronautics be not operated on an absolutely reliable and safe basis, the consequences are likely to be appalling. At least, well-directed efforts should be made to put and hold the industry to a high standard. In this respect, the old adage of an ounce of prevention being worth a pound of cure can be applied very well. I have actually seen a pilot take an airplane into the air with its upper wing tied to the struts with baling wire. This could not happen in any reputable organization. It should be an offense punishable by law for any man or for any organization to fly an unsafe airplane. The future of commercial aeronautics depends to a great extent upon the safety of the airplanes and the security of passengers.

Records should be kept of all repairs; then, if accidents do occur, they can be traced and responsibility can be established. In all inspection work, the inspector should at all times consider cost as well as quality, but consideration of safety should rule. Many errors are not unsafe; often, they occur where there is an unnecessarily high load-factor. In this case, the inspector should satisfy himself by actual calculation and not by

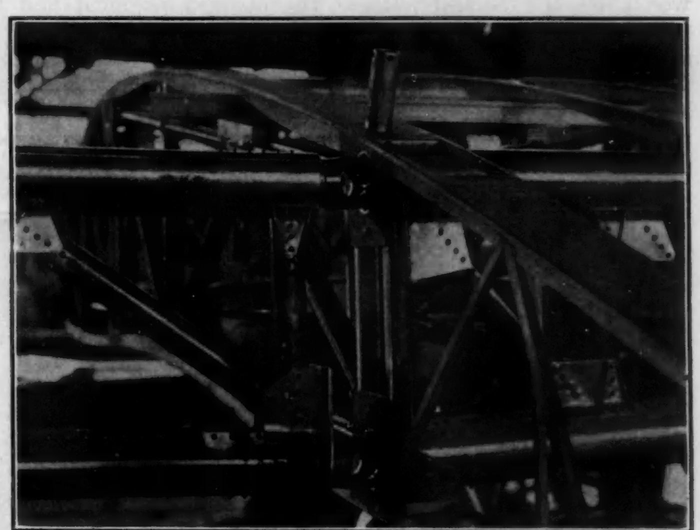


Fig. 3—Typical All-Metal Airplane-Construction
In the Fabrication of Metal Parts, All Operations Are Carried On with Great Care and Precision To Assure the Final Desired Result. Numerous Jigs and Fixtures Are Used to Facilitate Production, and the First Piece of Each Operation Is Brought to the Inspector To Be Checked before the Operation Is Continued

guesses. Experience is often a valuable aid in making these decisions, with a consequent saving in cost.

Each part of an airplane is designed to weigh a certain amount, an allowance of 3 or 4 per cent being made either way. The inspector weighs and records the weight of each item after its part number. A copy is forwarded to the engineers, who adjust these weights to suit the various assemblies. If the overweights accumulate too fast, a redesign may be necessary.

The Army and Navy have done a great deal of very

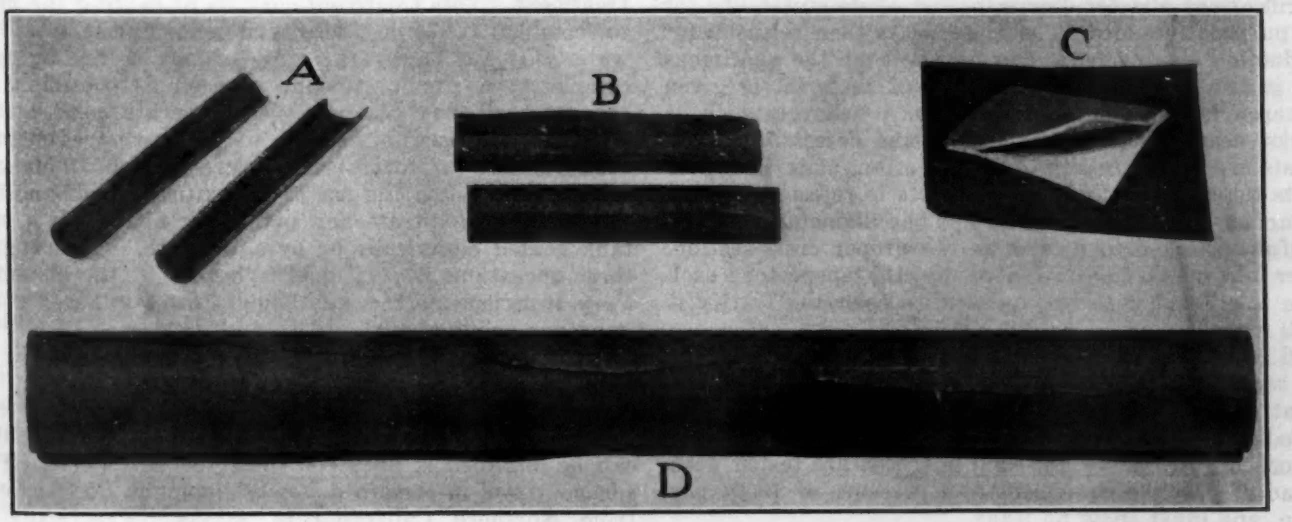


Fig. 4—Some Defects Found in Metal Parts
View *A* Shows a Steel Tube Having a Wall Constituted of Two Thicknesses of Metal and a Thin Portion at the Broken End. View *B* Illustrates a Bronze Bar That Is Solid Metal through the Center Only. In View *C*, a Defect in Sheet Aluminum Is Depicted. View *D* Shows a Seam on the Surface of a Steel Tube

important inspection research and maintain an office in the factory where contract work is being done. Practically all contact between the manufacturing organization and the Army and Navy representatives is through the inspection force. Many extensive tests are made to prove the airworthiness of the different elements of the aircraft and the accuracy of the engineering calculations.

Discussion of Materials

All materials used in aircraft should be light and easily workable, and should possess the desired physical and chemical properties; they must have the specified cross-section and be free from defects. All ferrous and non-ferrous material is held in bond as it is received. A sample is taken from numerous pieces and forwarded to the testing laboratory, where its physical and chemical properties are determined; a report of these properties is forwarded to the inspector for comparison with the specifications and for determination of its suitability for the purpose intended. The material is then released for production or rejected. During the time the specimens are in the laboratory, each piece of material is given a thorough surface inspection to locate defects such as cracks, seams and laminations. Some defects found in metals are shown in Fig. 4. Very often, material which meets the chemical and physical tests is rejected because of surface defects. The gage and the diameter are very carefully checked to determine the proper cross-section. After all metals are released by the inspector, each piece is painted with its conspicuous color to identify it at all times.

All copper and other tubing used for air, gasoline, oil and water lines is submerged in water and tested with air at a pressure of 15 lb. per sq. in. All defects are immediately cut from the piece and only good material is stocked. All valves and shut-off cocks are tested with a head of gasoline equivalent to a pressure of 15 lb. per sq. in. and must show no leaks.

Gasoline is received in large quantities and, before it is discharged into the storage tank, a sample is taken from the bottom of each compartment and forwarded to the laboratory where its initial boiling-point, its end-point, its specific gravity and the residue are determined. Hundreds of other items of material are used, and each one receives the same minute inspection and control to assure compliance with the specifications and the drawings.

Recent designs of aircraft provide for extensive use of aluminum and of aluminum alloy. Aluminum has no value as a structural material and is used only in places where there are no severe stresses, such as for engine cowls, seats and doors. The aluminum alloy containing copper and small percentages of other alloying metals has decided structural value. It is almost as strong as low-carbon steel in tension, has a modulus of elasticity about one-third that of steel and weighs about one-third as much. It works more easily and can be fabricated as readily. The distinguishing and noteworthy characteristic is the spontaneous aging effect after heat-treatment. This treatment consists of heating the metal to from 900 to 970 deg. fahr. and quenching it in boiling water. If further work is to be done before aging is completed, it should be done as soon as possible after the material has reached the temperature of boiling water. The essential feature of this heat-treatment is accurate and uniform temperature-control. This control is obtained by the use of a mixture of half-and-half molten sodium nitrate and potassium nitrate in a steel tank heated electrically or by a fuel fire. Each step in these operations is periodically checked by the inspector. Very injurious defects can come from overheating and improper cooling.

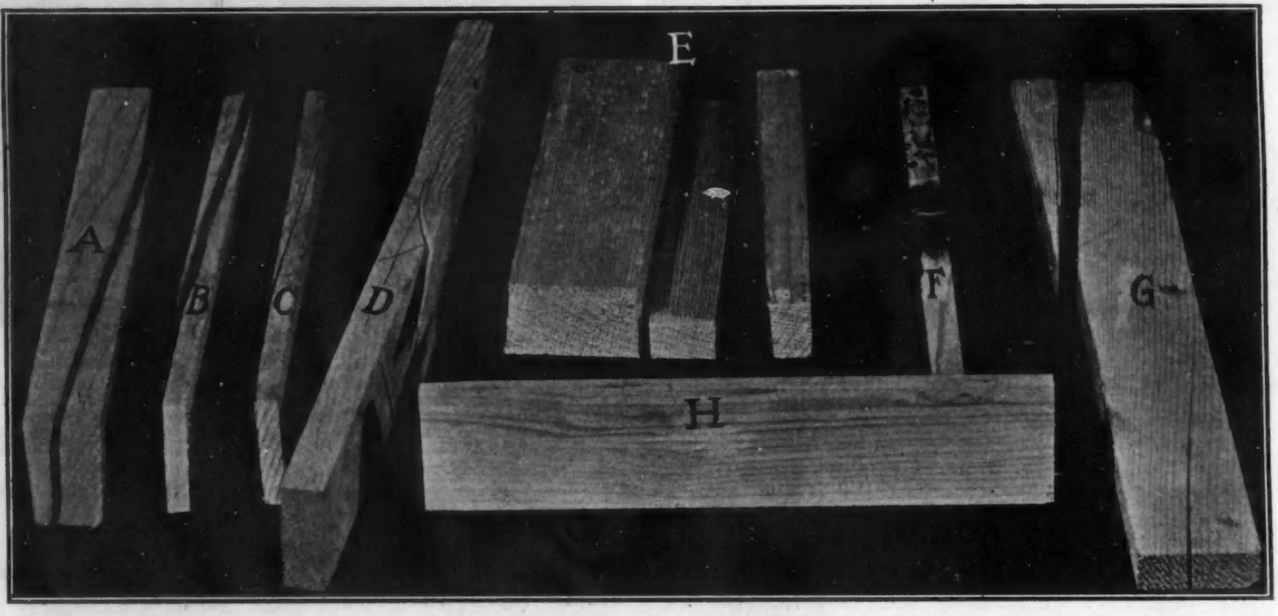


Fig. 5—Defects Frequently Existent in Wood
Views *A*, *B* and *C* Show Defects Due to Spiral Grain. At *D*, a Bad "Dip" Is Illustrated. View *E* Is an Illustration of How Good Wood Should Fail, and *F* Portrays a Failure Under Compression. Diagonal Grain Is Depicted at *G*, and a Defect Caused by an Injury to the Tree Is Indicated in View *H*

Wood for Aircraft

Wood is employed very extensively in aircraft construction. Only the highest grade of Sitka spruce that can be obtained is used for the important parts. This spruce grows in certain districts along the Pacific Coast from Northern California to Alaska. Practically all the very high-grade spruce is now obtained in Oregon. It is from this stand of excellent timber that material is obtained for use in aircraft. Each shipment is

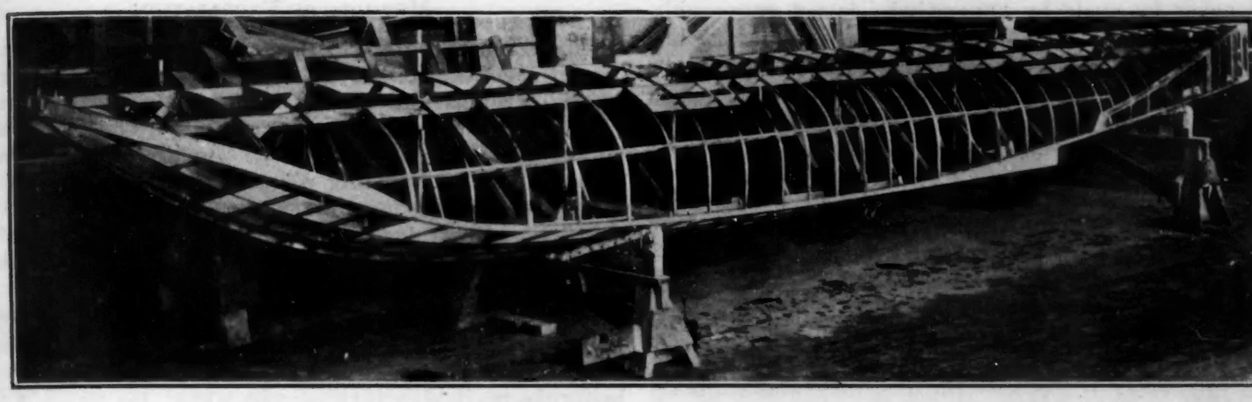


Fig. 6—Typical Pontoon Skeleton
Workmen of the Highest Type, Thoroughly Well Versed in the Art of Working and Fabricating Wood, Are Employed. Great Care Is Given to the Gluing and Nailing of All Wooden Assemblies and After They Are Completed, It Would Require Their Destruction To Dismantle Them

furnished against rigid specifications and, when received green, it is inspected on four sides by expert wood-technologists. Only material which meets the requirements of those specifications is accepted.

Ash and other hard woods are obtained from woodlots in the neighboring counties in Ohio, and only the best of second-growth timber is used. This region produces the finest grades of white ash and other hard woods. Of this lumber the inspector selects only the pieces of straight, tough, wide-ringed sap-wood. Strength and toughness are of greatest importance. These qualities are determined by analysis of the structures of the different woods.

Wood is made up of minute cells, arranged somewhat as the cells in a honeycomb, except that the cells are very much longer in proportion to their width than cells in a honeycomb, and are not as uniform. In the soft woods, the vertical cells are fairly uniform in shape and size, but in the hard woods they vary greatly, some being fifty times as wide as others. The wide vertical cells are called vessels, or pores, and the narrow ones are termed wood fibers. Between these vertical cells and fibers, and lying in a horizontal radial-direction, are the "medullary rays" which are composed of short, blunt, thin-walled cells similar to pitch tissue and are shaped like two-edged swords set edgewise.

The substance of which wood is composed is one-half as heavy again as water. It is organic, and consequently very complex in structure. The foundation of the cells which build up this structure is known as "cellulose," combined with another material called "lignin," which adds to the strength of the cell walls and gives them color. Each piece of wood has individual characteristics and must receive individual attention during inspection for quality.

All the wood is kiln dried or carefully stored for kiln drying after inspection of the raw material. The drying is done under the direction of the inspector; it is a much more difficult and refined operation than is required for most purposes and requires careful supervision. Samples are placed in the kiln and are weighed periodically to determine the moisture content and rate of drying. The kiln used is of the latest recirculating humidity-regulated type and is equipped with the most modern thermostats and regulating devices.

After drying, the wood is removed to the wood mill and stored under typical mill-conditions for a period of about 2 weeks. During the mill operations, the wood is carefully inspected and selected for its various uses, great care being taken to eliminate all harmful defects such as spiral grain, dips, knots and "dote," some of which are illustrated in Fig. 5. The selection of lumber

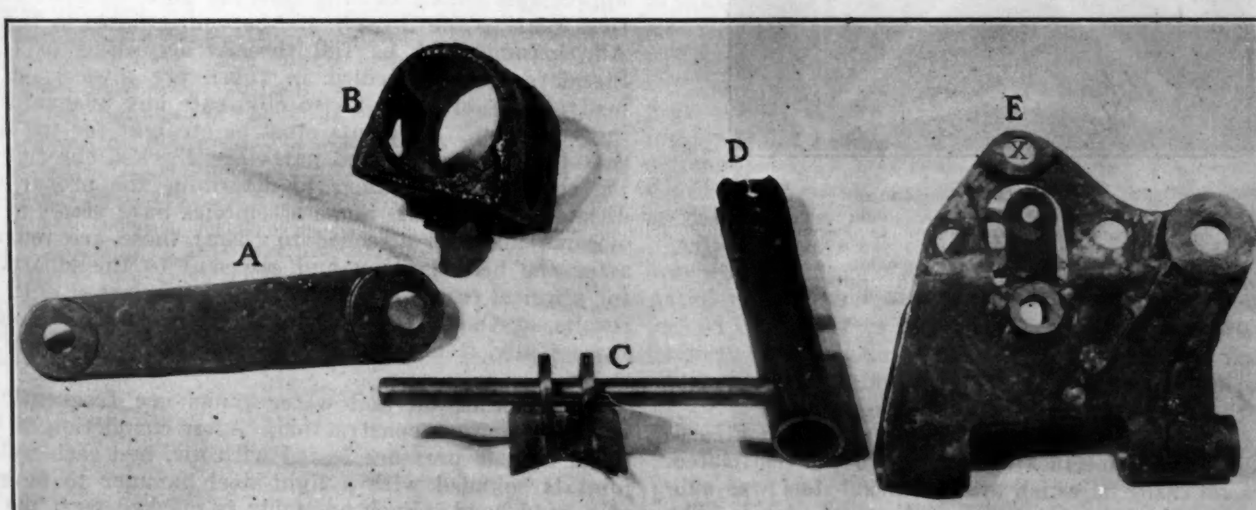


Fig. 7—Defects Causing Rejection of Fittings
A Hole That Has Been Bored Off-Center Is Shown at One End of Fitting *A*, and Another Hole in Fitting *B* Not Only Is Off-Center but Has Left Too Thin a Section of the Metal on One Side. In Fitting *C*, the Holes Have Been Drilled at a Wrong Angle. The Tube End of Fitting *D* Has Split, and Too Small an Amount of Material Was Left around the Hole Marked *X* in Fitting *E*

should never be made by anyone who is not thoroughly familiar with wood technology and lumber physics, because the popular interpretation of what constitutes grain is decidedly in error and many serious defects can be recognized only by an expert. The time is not far distant when the use of wood for structural purposes in aircraft will be eliminated to a great extent.

Steel that is not properly cold-worked or is very low in carbon, or in the annealed condition, very often does not show the physical properties desired. Material of this sort is often high in sulphur and in phosphorus contents. Sulphur is classed as an injurious element in steel, it being conducive to increased corrosion and segregations which render it unreliable. Phosphorus is a decided impurity; it reduces the ductility and renders steel "cold-short." All material used should give evidence of the possibility of failure before actual failure takes place.

For the amateur aircraft-builder to go into the open market and buy steel for his various structural purposes without specifications and proof of compliance is a decided and sometimes a fatal risk, as many cheap grades of material that appear perfectly sound are loaded with defects that possibly will cause failures.

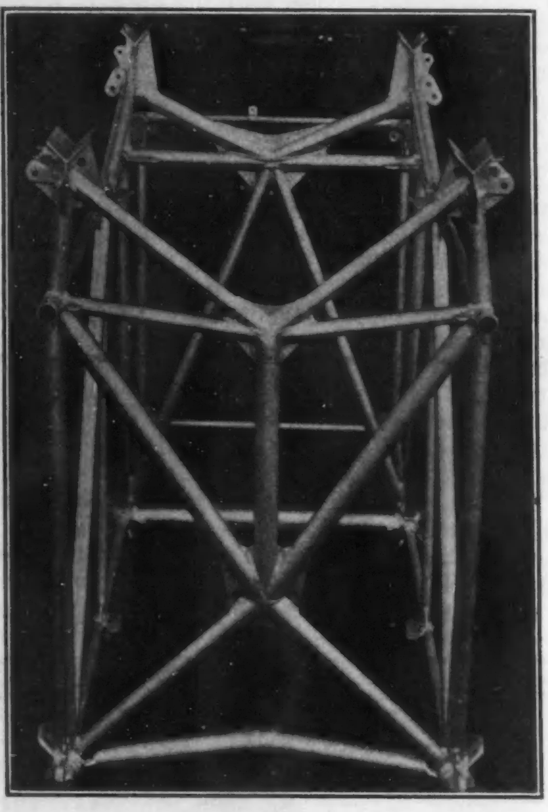


FIG. 8—A WELDED ASSEMBLAGE

Welding Is Done Very Carefully, Using a Neutral Oxy-Acetylene Flame. Inspection Is Focused on the Elimination of Cold Welds and Burnt Material. Large Assemblies of Welded Construction Are Held within a Tolerance of 1/32 In. All Operations Are Watched Constantly by Qualified Inspectors

The importance of building aircraft strictly according to design and specifications cannot be overestimated. I have seen cases in which alleged nickel-steel was submitted which contained not even a trace of nickel. The result of this predicament should be perfectly obvious, as alloy steel is ordinarily used in portions of the airplane structure which are very highly stressed when it is put into service.

METHODS OF FABRICATION

The machinery used in the fabrication of wooden parts is of the conventional type. Many special bending forms, special frames and jigs are used to assure the interchangeability of parts and assemblies. The personnel is of the highest type and is well acquainted with the art of working and handling wood. It is not uncommon for these men to produce wooden parts within a limit of 0.010 in. Great care is given to the gluing and nailing of all wooden assemblies and, after these are made, it would require their destruction to dismantle them. The glue used is waterproof, and very close inspection-control is maintained over the mixing and use of this glue. Many different kinds of wood are used, spruce and ash being the main structural woods, while "plywood" is used extensively in the rib and in the bulkhead assemblies. Veneer of mahogany and cedar is used in pontoon construction for decks, planking and bulkheads. A typical pontoon skeleton is shown in Fig. 6.

Many large assemblies are made to an exact centerline, and all wings are accurately squared before being shipped to the finishing room. Every step of the production of wooden parts is inspected, and accepted assemblies are marked with the individual inspector's stamp.

The machinery used in the fabrication of metal parts is of the conventional type. Very little special machinery is used. All operations, however, are carried on with the greatest care and precision to assure the final desired result. Numerous jigs and figures of special design are used to facilitate production, and the first piece of each operation is brought to the inspector for check before proceeding with the operation. As the parts and detail assemblies are completed, they are forwarded to the Metal Parts Inspection Department where they are closely examined for cracks which sometimes develop during fabrication. When this condition exists, it is cause for a general check upon the methods and materials to eliminate the possibility of defective assemblies. Some examples of defects in fittings that cause their rejection are shown in Fig. 7.

Each assembly is checked for dimensions against its detail drawing. All holes must have a uniform amount of material around them to develop the full strength of the respective part. All threaded parts must fit without appreciable shake, to eliminate the possibility of vibration wearing the threads and becoming liable to failure. All threads must be full threads according to U. S. Standard. Holes drilled in tubes are always on the neutral axis of the tube, to eliminate any unequal loading condition. All struts must be straight for the same reason. All heat-treated parts are checked carefully in the conventional manner to determine the proper condition of the metal. Some assemblies have pieces of the original material attached to them; these are removed after the heat-treating and are sent to the laboratory for physical test. The material is not released until the results of the tests are known; if it passes the tests successfully, it is released for further operations or for stock.

All gasoline, oil and water tanks are frequently of welded aluminum construction. After completion of this work, each is pressure tested with air, and each welded joint is sounded with a light-steel hammer to be sure of a good bond. Each assembly is marked with the individual inspector's stamp.

The matter of corrosion prevention is of great consequence. All tubes and tubular assemblies are dipped in hot mineral oil which will not become rancid with age,

or they are sand blasted and varnished with standard varnish containing aluminum pigment. All other parts and assemblies are zinc plated, which is the best known method for corrosion prevention.

The process of brazing is carefully handled. All parts to be brazed must fit with minimum clearance, be well cleaned and assembled carefully. The brass is composed of 50 per cent copper and 50 per cent zinc; these metals are melted in a crucible. When this alloy reaches the required temperature, the parts to be brazed are covered with flux, carefully immersed and held in the brass until all joints are well heated through. Any assembly which has a well-brazed joint of proper area will not fail where brazed.

Welding is carefully done with a neutral oxyacetylene flame, and is carefully checked to eliminate cold welds and burnt material. Some very clever welding is done on many difficult assemblies, one of which is illustrated in Fig. 8. Large assemblies of welded construction are held within a tolerance of 1/32 in. This is remarkable when the elements of shrinkage and warpage are considered. All operations are watched constantly by qualified inspectors.

Doping and Finishing

The fuselage and all surfaces are covered with a very strong cotton cloth sewed on with heavy thread and, in turn, the whole structure is then sewed and tied to the frame with heavy cord. Sewing thread, cord and cloth are all fully tested for compliance with specifications. All surfaces are then impregnated with a compound having a cellulose base, called "dope." This renders the cloth airproof and waterproof, and also shrinks it tight to the frame. An example of a wing covered in this manner is given in Fig. 9. The actinic rays in light have a damaging effect on this fabric and soon destroy it if it is not protected. The protection is accomplished with a powdered-aluminum pigment in varnish or dope; it is sprayed on. Very smooth surfaces result from this treatment. All operations are inspected as they proceed, and when finished. All wooden parts receive two coats of varnish, and all metal parts are covered with two coats of a mixture of aluminum and varnish.

Final Assembly

The final assembly of the fuselage is checked for trueness, for location of wing attaching points and for the attaching points of tail surfaces. All struts are plumbed and leveled. The engine bearer is checked for being level both longitudinally and transversely. The interior mechanism of controls, tanks, instruments, floors, seats, the engine and its controls, radiators, gas, oil and water lines and the like are then installed all thoroughly inspected. The fuselage is then sent to be covered and doped.

The inspection of this assembly is very carefully done to eliminate any eccentricities, bowed struts, or wires which may be too tight. The security of all fastenings and the general workmanship are inspected to assure maximum strength and durability and to maintain the reputation of the company for excellence and appearance of its product.

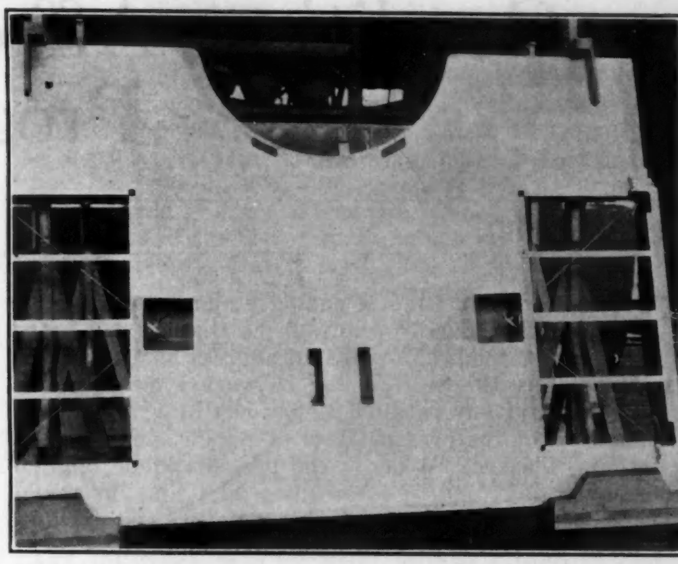


FIG. 9—A COVERED AIRPLANE-WING
The Fuselage and All Surfaces Are Covered with a Very Strong Cotton Cloth Sewed On with Heavy Thread, the Whole Structure Then Being Sewed and Tied to the Frame with Heavy Cord. Sewing Thread, Cord and Cloth Are All Fully Tested for Compliance with Specifications. All Surfaces Are Then Impregnated with a Compound Having a Cellulose Base, Called "Dope," Which Renders the Cloth Airproof and Waterproof and also Shrinks It Tight to the Frame. For Protection against the Actinic Rays of Light, Which Otherwise Would Have a Destructive Effect, a Powdered Aluminum Pigment in Varnish or Dope Is Sprayed On. Very Smooth Surfaces Result from This Treatment

Final assembly is started after the fuselage receives its cover and finish. The wings and landing gear or pontoons are attached and the final line-up is begun. This line-up consists of leveling the fuselage, truing the wings and tail surfaces, and establishing the angle of incidence. This is all done to establish the maximum efficient flying attitude. The propeller is installed and tracked. The machine is then weighed and the engine installation is thoroughly tested. All line-up operations are inspected, the gasoline lines are checked for leaks and every detail of the machine is thoroughly gone over to assure completeness of detail and workmanship. Each airplane is finally tested for complete electrical bonding to make sure that all parts of the machine are in good electrical contact. The purpose of this is to connect the entire structure into a counterpoise for the radio, which eliminates unnecessary noises in radio reception and prevents accumulation of static and its consequent sparking between metallic members. All these inspections are accomplished by men who are qualified engineers and who are thoroughly acquainted with all the requirements of the airplane.

After inspection is completed, the airplane is turned over to the flight-test pilot for a thorough work-out. After the flight test, the airplane is dismantled and packed in cars, after which the details of the packing are inspected.

THE USE OF WORDS

THOUGHT, which in its own nature always was free, discovers its freedom first in science. Language henceforth falls into its place as the mere servant of thought, and science treats it despotically, making it mean first what it likes. With this consciousness of its mastery over language, thought attains its majority. The whole mind is concentrated on the problem of meaning. This revolution in the use of language is the birth of science.—R. G. Collingwood.

Conditions Affecting Aeronautic Progress

By C. M. Keys[1]

Aeronautic Dinner Address

THIS morning I met a publicity man, an instinctive "headline hound," who told me that he had heard that I intended to make an address about aviation matters before the Society, and he warned me earnestly not to do so, at any rate not to say anything in particular, in view of the present state of public opinion about aviation. I asked, "What is the present public opinion about aviation?" and, if I had given him time, he would have spent the whole afternoon enunciating and explaining all of the points of view about aviation. However, I told him that there was not, so far as I knew, any public opinion on the subject, although about a million ideas are afloat as to the various phases of aviation. I feel, therefore, that I can say what I wish to say.

There is important news in aviation. I believe that the definite entry of Henry Ford into commercial aviation, even though he came in on an experimental basis, is the most significant news of the year. It is big news principally because, in coming in, the Ford interests really were answering what seemed to be a definite call from the public of the United States for aviation on a respectable scale.

Some days ago a reporter called on me with a grievance. He said that he had been reading some testimony that I had given before a Congressional committee last winter to the effect that I was retiring and withdrawing my capital from aviation and that I was not interested in going on with the development of commercial aviation, but that only a couple of months later he had read in the papers that I had become chairman of the executive committee of National Air Transport. He wanted to know just what my attitude is.

The fact is that a miracle happened last winter. A Congressional investigating committee really started something besides headlines. An enormous pent-up demand for some action in the air must have been dormant in this Country. Somebody, somehow, must have touched the spring that released these dammed-up forces. Within a period of 30 days, 1625 editorials from all over the United States flowed into my office. Practically without exception, they all voiced the sentiment of the people that we must have aviation, both military and commercial, in this Country.

I believe that Mr. Ford and his associates felt the same strong compulsion that I felt, and that Leonard Kennedy, Trowbridge Calloway and many other men who were growing tired in aviation experienced at about the same time. To have retreated under these conditions would have been plain cowardice. When the people of the United States want something, they intend to have it. It may be a hard task to give it to them but, in the long run, it will be a profitable and honorable undertaking to do so.

It was this change in public sentiment, exceedingly marked to anyone who was close enough to the situation to understand it, that brought about, not only the Ford development, but also the National Air Transport, and that has brought about a dozen or more sound developments of the same sort throughout the Country, and, of course, also a flood of unsound ones seeking merely to sell stock on the strength of the wave of public sentiment.

Small Industry Makes a Big Noise

This little aviation industry always has been a tremendously troublesome and noisy infant. It is a very small industry; you could take the whole airplane and airplane-engine industry of the United States and lose it in a single sub-department of the General Motors Corporation, or the United States Steel Corporation, or any other major unit in the great manufacturing industries of the Country, but it receives more front-page publicity, good, bad and indifferent, truthful and otherwise, in a normal month, than any other industry that I know of could get in a normal year. That is one of the main troubles of the aviation industry; it makes us take ourselves too seriously.

One day, when I was a newspaper reporter, before I reformed and became an editor, I called on old "Jim" Hill. He had just been made the defendant in a lawsuit by a man who claimed that *he* had been responsible for getting Mr. Hill started in the venture that became the Great Northern Railway, and he wanted a share of the profits. The amount for which he was suing was only a few million dollars, nothing at all to us airplane men, who can be sued for $52,000,000 any time without turning a hair, but it made the King of the Northwest angry. He spluttered:

> That fellow reminds me of a fly in a powerplant. The great flywheel was standing still and this fly flew down and alighted on it. Soon the wheel began to turn and in about 2 min. it was going around so fast that the spokes could not be seen. The fly flew up to the ceiling, looked down at it and remarked to itself, "See what *I've* done." He thought, in fact, that that was why they called it a *fly*wheel, I suppose.

That is like our state of mind in the airplane business. Because some of the great forces of the world, the demand for the fastest kind of transportation and for the most efficient weapons of war and the political jealousies of great nations, start in motion the huge flywheel that represents forces strong enough to drive us on in this big job; because public opinion in the United States demands airplanes in great numbers and of the best capabilities; because France's fear of Germany keeps her always armed to the teeth; because England's far-flung empire demands that in that hard-ridden nation, in spite of poverty and unhappiness, the best shall be none too good—for these great reasons we, little people in a little trade, are driven onward to accomplish, step by step, the conquest of the last and most stubborn of the elements to be conquered.

Glenn Martin, Grover Loening, Mr. Boeing, Mr. Lawrance and I are likely to think, every now and again, like

[1] President, Curtiss Aeroplane & Motor Co., Garden City, N. Y.

the fly in Hill's powerplant, that we start something. If we would remember that, either as individuals or as heads of corporations, we amount to nothing in this great current of affairs, we should all be happier and better off, and aviation would stop making so much noise and would accomplish more, perhaps.

Enlivened by Investigations and Bombs

You may understand a little better the atmosphere in which this curious noisy little art exists when I tell you that since 1918, the period with which I am personally familiar, the aviation industry has been investigated 23 times. Some of these investigations have been wonderful. The first that I remember was conducted by Gutzon Borglum, the sculptor. From the point of view of art, that was the most successful investigation so far made. The business of a sculptor is to make busts, and it was undoubtedly a great and complete "bust".

Times have been dull when no investigations were in progress. Some of them, like the one that resulted in the Hughes report, were splendid investigations. Some were mere duplications, as when, for instance, the Senate and the House of Representatives, through different committees, looked into matters 5 or 6 years ago. I do not know whether either of them ever published a report; if they did, certainly nothing was done about it.

One never can tell what an investigation will accomplish. Without doubt out of the Congressional investigation came a much better and more complete understanding of the facts and a much more helpful Governmental attitude toward the job of putting America first in the air. Therefore, while it is true that nothing has resulted from more than half of the investigations so far made, we are always hopeful and, indeed, inclined to be happy, when somebody suggests another one.

So that you may still further understand this foolish little industry, I want to call attention also to the extraordinary conditions under which we have lived for the last year or so. The air has been full of bombs. Everybody, particularly "Bill" Mitchell, has been scattering them around. I was interested to read, a few days ago, in some testimony given by a naval officer, I believe, before the President's Aircraft Board, that the Navy is still using the same bomb-sights that it was using in 1916. I think we should all be glad of that, for, if they had not been doing that and had been able to hit somewhere near where they wanted to hit, nobody knows what would have happened.

A little crowd of earnest muck-rakers started an investigation last year. They fired their verbal bombs at the industry but they hit the Army and the Navy, in large part. Mitchell's bombs were aimed at battleships and admirals and other things that ought to make good targets. I sometimes think, however, that "Bill" really did not care much where they landed, so long as they exploded and made a big noise.

So you will find, if you look the matter over, that nobody who started anything in aviation during the last year or so had the slightest idea where he would finish. He usually ended by accomplishing something that he never dreamed of doing when he started. In aviation, as a matter of fact, we have no idea where we stand. My companies have specialized in speed and attained a fair degree of it, but our hardest work has not been on speed at all but rather on several other characteristics that ultimately will prove to be more important. The only thing that we are sure of in aviation is that a change, a great change, will occur.

What the Public Is Interested In

It is not my business, and I do not know that I am greatly interested in the question, whether we have two Air Services in the City of Washington, or a half dozen, or one. Personally, I do not care whether or not there is a corps in the Army and a corps in the Navy; in fact, I have no opinion of any value about how an army or a navy should conduct its affairs. That is all up to the civil arms of the Government, which still rule the Army and the Navy. But it does seem to me that when the people of the United States began last winter to demand aviation, they made no distinction between commercial and military aviation. They want both. They do not want any Englishman, or Frenchman, or German, or Italian or Japanese to be able to write the kind of stuff that has been running in the foreign journals about the aircraft and the air services of the United States. They do not want our observation aviation in the Army to be described as made up entirely of "obsolete British airplanes built in Ohio." They do not want the pilots of the Army and the Navy, who comprise as fine a body of soldiers and sailors as ever wore uniforms, to do nine-tenths of their flying in ships built in the time of the World War, no matter how thoroughly and soundly those ships may have been rebuilt. Those airplanes are obsolete as to performance, outofdate as to appearance, and dangerous, not only to the lives of the men, but to the morale of the Service, which is more important.

Fully Abreast of Europe in Design

The people of the United States have made their views heard during the last few months in no uncertain terms. I do not believe that they are interested in the form of organization under which the Army and the Navy proceed, so long as they do proceed. It seems to me that it would be the part of wisdom to hurry-up and get through with questions such as this and come down to brass tacks and do the job somehow.

Some questions in aviation are of vital interest to the people and have nothing whatever to do with controversies about air services, corps and so forth but have everything to do with performance. The people want to know whether we are ahead of Europe or behind it in our ability to create types of aircraft and engines and in our ability to build them. They are confused by the diversity of statements on this subject. In one paper they read testimony to the effect that in certain types of airplane, notably, perhaps, the pursuit types and the amphibian, we boast that we are the equal of the best builders and designers in the world. In another paper they read that our Army and Navy aviation is absolutely obsolete, that all of the flying is done in outofdate ships, and that the Country is absolutely a nonentity so far as competition with foreign nations is concerned.

Both statements, utterly divergent as they seem to be on their face, are true in large part. A few nights ago I dined with Mr. Fairey and Mons. Breguet, the former being probably the largest builder of airplanes in England and the latter the largest builder of airplanes in France. Both have splendid staffs of design engineers. Neither of these men will challenge my statement when I say that in this Country, so far as the design of the fast major military types is concerned, we are abreast of England and of France. We do not fear comparison in either engines or airplanes. Our types of engine are by far too few, but those types can and will be increased when, as and if they are needed. We have little to learn from Europe at this moment in pursuit engines, in the complete development of fast fighting-ships, in two-place

ships, or, indeed, in any of the fundamental requirements of the engineering phases of this art. We have the men and the technical equipment and the technical knowledge to carry-on and to maintain a place alongside the great designing and engineering firms of Great Britain and of France.

Europe's Policy and America's Lack of Policy

There the favorable comparison stops. France and England long ago adopted the theory that the heart of military aviation is the aviation industry, and their policies have as their very foundation the maintenance of such an industry in proportion to their peace-time needs. They have concentrated the building-up of that industry upon the units that have at all times maintained strong engineering forces and created new and useful types. In this Country no such policy has been followed; in fact, we have had no policy at all until very recently, when the Army adopted from the Lassiter Board report certain fundamental principles that it has followed as closely as it can under the present law and regulations.

The consequence of this difference between America and the European nations is easy to see. There are four or five English firms and, I believe, a larger number of French firms, each of which is three or four times as big in personnel and in volume of product as is the largest of the American companies. That is the difference; in fact, it is the only difference between the situation in Europe and the situation here.

Until recently it has been the conviction at the City of Washington, I believe, although of course it never was expressed in so many words, that this was what the public wanted; that all would be well so long as we kept a few world's records hanging on the wall; and that it did not matter much what was behind this show-window.

Admirals and Generals Now Asking Questions

All of this seems to have changed. Very earnestly and with a great display of intention, a considerable number of admirals and generals, to whose minds a year ago the airplane was the crowning impertinence of all the ages, are asking questions about airplane performance, types and designs, and are beginning to draw what must be very painful comparisons indeed between the standard equipment of various branches of the Air Service in both the Army and the Navy and the standard equipment of similar branches in other armies and navies. In fact, a great and eager stirring is apparent in the splendid military and naval boards that control the military destinies of the United States. The Navy General Board and the Army General Staff control the United States from a military point of view. Admirals and generals must take their policies from the consensus of opinion of these boards or they will not succeed as admirals and generals.

In the Navy General Board is gathered together what I firmly believe to be the most splendidly equipped group of senior naval officers that exists. In all branches of naval activity these men are among the leading experts of the world. They know in detail all that goes to make a navy, and they know it at least as well as anyone else knows it. The very heart of their policy is honest intent and serious studious operation toward the only aim that they have, namely, to keep the United States Navy equal to any navy in the world. If any man should go before that Board and ask the number, the name, the year of design, the weight of armament, in fact, any detail about any ship in the American Navy, he would receive an immediate and correct reply without reference to notes or records. More than that, if he were curious to learn the age, the character and the ability of any ship in any important foreign navy, details right down to the weight of its broadside, for instance, he could get an immediate answer from members of that Board right out of their heads. In short, they are among the world's leaders in knowledge and thought in all naval matters. Much the same thing is true of the Army General Staff. No American has any reason to be ashamed of or critical of these organizations, as military organizations. They stand at the very top of their professions in the world today.

Navy Board Ignorant on Aviation Subjects

Now, reverse the picture and look at the other side. I have been before a committee of the Navy General Board. So far as I know, not a representative on that great Board knows a thing about aviation, either general or naval, beyond a very general smattering of incomplete knowledge based upon hearsay. It is doubtful whether even today the whole General Board knows the number, the name, the year of design or the flying ability of any of the naval units in aviation in the American fleet, let alone any other fleet. A year ago it certainly did not know.

The most astounding statements come from these gentlemen with regard to aviation. One of them told me, for example, less than a year ago, that the best long-range naval airplane ever built was designed and built by the United States Navy 7 years ago. Naturally, I was confounded; so I asked him what ship he meant, and he named the NC-4. That startled me a bit, and I said, perhaps rather impolitely, that, notwithstanding the fact that the Curtiss Company designed and built the NC-4 that flew across the Atlantic, it is today as outofdate as Noah's Ark.

Recently an admiral who was sailing to take up his post abroad, made the statement to a reporter, apparently in all seriousness, that Great Britain is abandoning her separate air-service. Great Britain is not doing this, has not even thought of doing so, and, with the conditions under which she has to operate airplanes, probably will always maintain some form of separate air-service. The admiral probably had read in some of the British naval papers, or elsewhere, echoes of the struggles that have been going on between the British Admiralty and the British Air-Force, as to whether or not the airplane-carriers with the fleet, together with their personnel, should be controlled by the navy or by the air force. So far as my knowledge goes, that is about the only important question concerning the air force which has even been up for discussion in Great Britain.

Again, the United States Navy has done some very painstaking work in the last year on the important question of the power of bombing airplanes against battleships and vice-versa, and the ground-defense section of the Army has worked hard to develop the possible uses of anti-aircraft guns against such airplanes. In both cases the calculations are based upon the only bombing airplanes that the Army and the Navy have, namely, the Martin. This airplane was designed in 1918 and is distinctly a 1918 ship. It was excellent in its day, and Mr. Martin should be proud of it, not only for its performance but for its long life. It has a theoretical speed, loaded, of 100 m.p.h. and an actual speed, all out, in general practice of less than 90 m.p.h. It has a theoretical ceiling of about 10,000 ft. and an actual ceiling, loaded, of probably below 9000 ft. It has a maximum range off-shore of about 250 miles and return. If the value of bombing airplanes and of anti-aircraft guns is

to be calculated on that basis, the Navy certainly should use wooden frigates as targets instead of uptodate battleships. All the world knows that, if anybody will pay for them, any one of a dozen companies in the world can and will build machines that will carry the load of the Martin bombing airplane at a speed of 125 m.p.h., achieve a ceiling of from 16,000 to 20,000 ft. and have a range offshore of at least 600 miles. It is one thing for an anti-aircraft gun to hit an airplane flying at 90 m.p.h. at 9000-ft. elevation and a very different thing to hit the same airplane traveling at 125 m.p.h. at 18,000-ft. elevation.

Some Strong Man Will Compose the Situation

To formulate the present policies, let alone the future policies, of armies and navies on an assumption that the development of aircraft has reached a stagnant condition, like the development of doorknobs, for instance, is plain nonsense, and all of the world knows it. This condition, or perhaps one might better say, lack of condition, is breaking-down in both the General Board and the General Staff. Probably the awakening of both the Army and the Navy on aircraft matters will go forward rapidly, even if the organization for aircraft in the City of Washington is not changed at all, and in a very short time the most complete and accurate information concerning aircraft in the United States will be not only in the files of the General Board and the General Staff, but also in the minds and in the hearts of strong and forceful members of those boards.

You have heard of General Lejeune, commandant of the Marine Corps. He is the kind of man that gets things done. That is one of the main reasons that the Marine Corps is what it is. After awhile, no doubt, a pair of Lejeunes of the air will be sitting on the General Board and the General Staff, when the General Board and the General Staff are not sitting on them. Then, and not until then, will conditions improve to any appreciable extent.

I have observed that when these great upheavals occur, in the affairs of ordinary life, in local politics, in military affairs or in financial affairs, always in the Anglo-Saxon races a man arises to do the job of straightening out and composing things and starting them on their way again. The great financial forces of New York City did not stop the panic of 1907. J. P. Morgan stopped it. Great forces are of no value without a man to wield them. Our West was not opened-up by capital, it was opened-up by Hill and Huntington, as leaders of capital and of enterprise. Bismarck made the German Empire and Cecil Rhodes made South Africa. Keep that in mind as you watch this aviation situation untangled and you will, in all probability, see an ancient phenomenon repeated.

A WORLD AFRAID OF PRODUCTION

The post-war world has developed an absolute obsession —a fear of production. For the past century and a half, power machinery and a constant succession of mechanical inventions have been bringing luxuries to the masses of men unknown to the kings of earlier generations. Consumption has kept pace with production. Our 100,000,000 people consume vastly more than the 400,000,000 people of China —because they produce more, and so can afford to consume more. And yet we fear reviving production in Europe, and fear to let Europe send us goods to pay her debts to us. Labor fears production. English labor systematically resists new labor-saving inventions, and holds down output on the theory that if all the work is done today there will be none to do tomorrow. It is easy for the business man to see the fallacy of this. But he may easily be carried away by the similar fear that if imports come in they will use up domestic demand, and leave just so much less demand for domestic products. Both err in failing to see that demand itself expands and grows with production and trade. Supply of one product constitutes demand for other products. Imports, of themselves if for no other reason, constitute a demand for exports.

Imports coming in as payment for debts do not lessen domestic demand for domestic products. Rather, they increase by an equal amount the buying power of the Country. If French goods are sold in our market, and the dollar proceeds turned over to our Government, our Government may do one of three things: (1) It may remit taxes, permitting our people to buy more goods; (2) it may pay off public debt, increasing the funds in the capital market to be invested and spent; (3) it may engage in increased governmental expenditure, which again increases the total volume of demand in the Country.—B. M. Anderson, Jr., in *Chase Economic Bulletin.*

AUTOMOTIVE RESEARCH

(*Concluded from p.* 418)

brication the wear increases with greater sliding action, but these tests indicate that the amount of sliding and the amount of wear are not necessarily proportional

(6) Combinations of factors or conditions that cause excessive vibration have a detrimental effect on the durability of gear teeth

(7) Surface pressure is the most important of the factors that affect durability. Apparently for any pair of gears a critical surface pressure, governed by the properties of the materials exists, above which the life of gears is short and below which the gears will run indefinitely without appreciable wear.

(8) For unhardened gears under constant load and free from impact loads the allowable tooth loads based on the Lewis formula for strength are in excess of those permissible for satisfactory durability

(9) Unhardened gears for constant load transmission should be designed on a basis of durability rather than of strength. A gear tooth that is durable for a given load will, in general, be amply strong

In conclusion, it may be stated that all the tests were carried out on a Lewis testing-machine. We have already called attention to the suitability of this machine for accurate gear-tests in an article in The Journal[5].

It is hoped that sufficient interest can be aroused to carry on some further tests on gears of diameters similar to those commonly used in motor vehicles. The gears experimented with at the University of Illinois are of relatively large diameter and ratio. However, it is reasonable to assume that the two sets of results given apply fairly well to transmission and timing gears.

[5] See *The Journal*, July, 1925, p. 35.

Vol. XVII November, 1925 No. 5

Hot Stampings and Their Production

By G. F. Keyes[1]

Production Meeting Paper *Illustrated with* Photographs

ABSTRACT

WHEN production is on a small scale or when it is necessary to get into production in a very short time, the making of sheet-metal fenders, body panels and other stampings by the hot-stamping process is to be considered, as it is possible by this process to make very difficult stampings in less time and at considerably less cost for the dies than by the cold-stamping method. Moreover, the hot stamping is a better product than the cold stamping, as it follows faithfully every contour of the die and retains its shape, having no tendency to "spring back" from form. The skill and perfection attained in the hot-stamping process are the results of more than half a century of development, outstanding examples of which are heroic-size statues on public and corporation buildings and in municipal parks. With the advent of the automobile, the skill of the artisans was turned to automotive sheet-metal work.

Dies for hot stamping are made of semi-steel castings with their faces built-up of a number of "pick-up" forms about 1 in. thick made of lead hardened with antimony, which are cast in molds made from wood or plaster-of-paris models. From three to seven "breaking-down" operations are usually required for producing the finished stamping without wrinkles, buckles or other defects. The "pick-ups" for these several operations are built-up on the face of the lower die and each "pick-up" represents one drawing operation. After each operation, one "pick-up" is removed from the lower die and attached to the upper die. These operations are performed on cold sheets. In the final operation the stampings are heated cherry red and run through the press under a lead die faced with a heavy-gage stamping lined with asbestos. After cooling, the stampings are run through the die with irons attached to sharpen all corners, to set beads and to take out shrinkage caused by cooling.

PRODUCTION requirements determine the advisability of making large automobile stampings by either the hot or cold-stamping process. There is a definite point in the scale of production below which hot stampings are cheaper than cold stampings, considering the small cost of hot-stamping dies as compared with the expense of double-action dies for cold stamping. A decided saving is possible by hot stamping in small production. The process is considerably more complicated than cold-drawn stamping and does not fit in with large production, but when small production is contemplated, or when it is necessary to get into production in a very short time, the hot-stamping process is the one to be considered, as it is possible by this method to make very difficult stampings in a relatively short time and the cost of tools is much less than the cost of cold-drawing tools.

Another advantage of the hot-stamping method is the faithful accuracy with which the parts are produced. From the standpoint of quality, the hot stamping is by far the better product. Hot stampings follow every contour of the die and retain their shape perfectly.

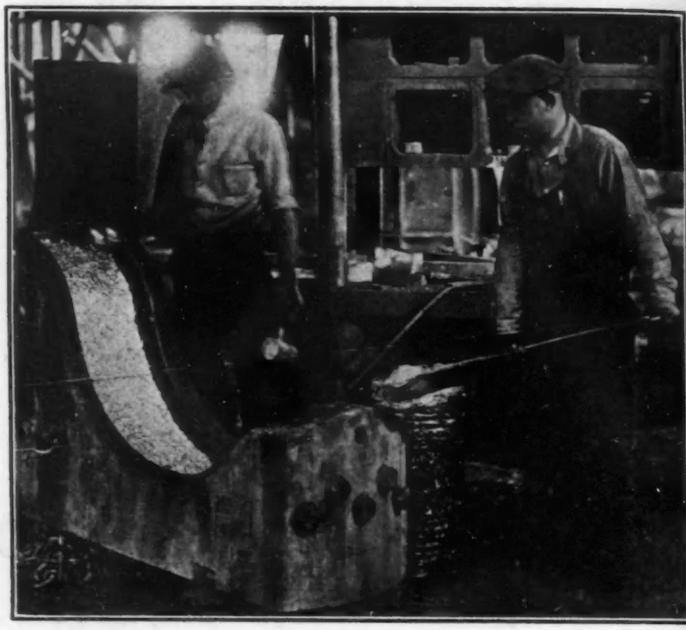


Fig. 1—Molding "Pick-Up" for a Fender Die
Ladling Molten Lead Hardened with Antimony into Male Die for Front Fender. A Series of "Pick-Ups," Each About 1 In. Thick, for Successive Pressing Operations, Is Made in This Way After the Die Has Benn Cast in a Mold Made from a Wood or Plaster-of-Paris Model

There is no tendency to "spring away" from the form, as there is with cold-drawn work. Steel of heavier gage can be worked hot, and, even though the stamping is of difficult design, every detail will be followed faithfully in the stamping. In some cases, when particularly deep draws must be made, such as a front-fender tire-carrier well 6 in. deep, there may be as many as 13 operations in forming the piece, but when it is finished it is surprisingly strong.

The marked economy of production, especially in comparatively small quantities, is of signal importance to many automobile manufacturers. Popular demand has its influence on designers and, as new general features are required, particularly in body lines, the small or exclusive car builder can readily make necessary changes at nominal cost.

Dies Are Cast from Models

Making of the dies for hot stamping is particularly interesting from the mechanical standpoint. Wax, wood or plaster-of-paris models of the stamping to be produced can be used. The type of model is determined by conditions. If the designer prefers to make an outline drawing of a fender or body panel, for example, and to work out details in the model, wax is the best material to use for molding the model, as, because of its plasticity, changes can be made with very little effort. Plaster models are used when a reproduction of a hand-built body or fenders is desired. A plaster cast can be taken from the sample panels, a re-cast made therefrom and

[1] Sales engineer, Mullins Body Corporation, Salem, Ohio.

the re-cast set up in the form of a model. Wood models, made in the conventional way, are preferred when complete body drafts are available and the design is predetermined.

FIG. 2—READY FOR FIRST "BREAK-DOWN" OPERATION
Front-Fender Die in Press with All "Pick-Ups" in Place in the Lower Die and Heavy-Gage Plate on Top Ready for Pressing. The Plate Is To Be Used for Facing the Upper Die

The next step after the models have been finished is to take-off plaster casts from them. These casts are then built into patterns representing finished dies and semi-steel dies are cast from these patterns. This requires a special set-up in the foundry so that the dies will come out of the sand molds true to pattern. There is enough shrinkage in the metal to allow for finishing the die surfaces. In some cases the spotting casts are made from the die pattern, depending upon the method of machining the dies; otherwise, the die pattern is set-

FIG. 3—REMOVING STAMPING AFTER FIRST "BREAK-DOWN" OPERATION

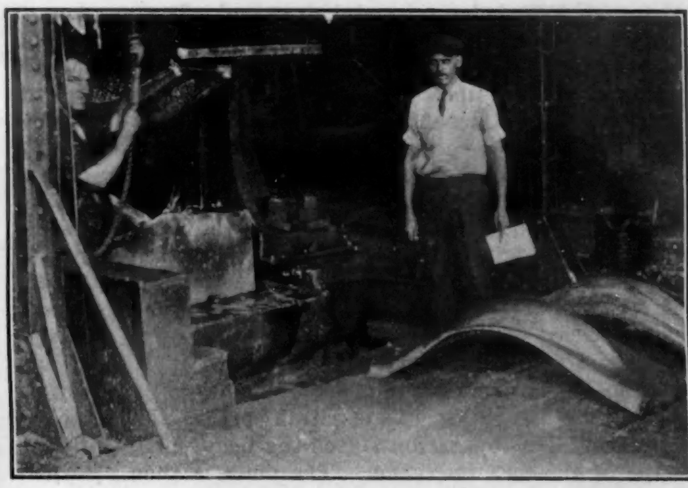


FIG. 4—OPERATION WITH FINAL "PICK-UP"
Front Fenders with Deep Tire-Well Stamped-In by Successive Operations

up on the Keller machine, which reproduces the die pattern, leaving the die ready for final finishing. The dies are then planed and drilled to fit either the drop-hammer or the single-action press.

MAKING "PICK-UPS" FOR THE "BREAK-DOWNS"

At this point, the skill of the operator comes into play and his experience is of inestimable value. He is able, by studying the blueprint, to determine the number of

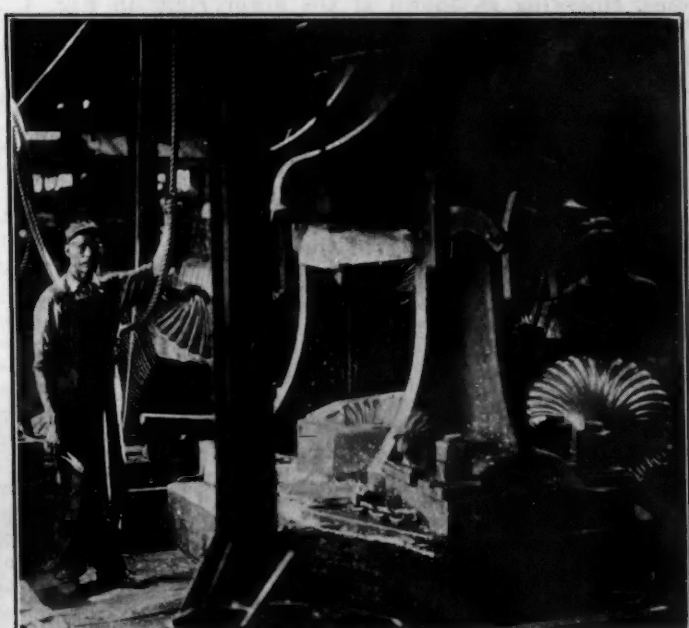


FIG. 5—DROP PRESS SET FOR LAST OPERATION IN STAMPING STEEL SHELLS
This Is a Good Example of How a Difficult Stamping Can Be Made by the Hot-Stamping Process

"breaking-down" operations that will be required to produce the finished piece without buckles, wrinkles or other defects. This having been decided, he proceeds to build-up the face of the female die with successive layers of lead hardened with antimony. Upon the way in which these lead "pick-ups" are poured depends the successful operation of the die. A "pick-up" represents one drawing operation. It is made by pouring lead from a small hand-ladle upon the clay-coated surface of the female die, as shown in Fig. 1. This requires real skill and a

thorough knowledge of metal drawing. The number of drawings that will be necessary to make the stamping is predetermined and the die is filled with the requisite number of pick-ups. The number usually runs from three to seven, depending on the depth of the draw. Pick-ups usually are made 1 in. thick.

After all of the pick-ups have been made, the die is set in the press to have the male portion of the die cast. An improvised mold is made around the top of the die and is lined with clay. This mold is then filled with molten lead to form the male die. As soon as the male die is cold, it is attached to the ram of the press and raised clear of the mold, then a heavy-gage plate is placed on top of the pick-ups, as shown in Fig. 2, and the top die is dropped, if a drop-hammer is used, or, if the die is set in a single-action press, the plate is squeezed. This operation forms the heavy plate into the shape of the first operation. The plate is then attached to the face of the upper die and stampings are run through the press and partially formed. This operation is performed with the sheets cold and is called "breaking down." This procedure, which is illustrated in Fig. 3, is repeated until all of the pick-ups have been removed from the lower die and attached to the upper die, by which time the metal of the sheets has been drawn to its elastic limit.

A new upper die, conforming to the exact shape of the semi-steel die, is next made. The new die, which is of lead, is faced with a heavy-gage stamping lined with asbestos to protect the lead from heat. The stampings are then heated to a cherry red and run through the dies, emerging as shown at the lower right in Fig. 4. This operation requires considerable skill, because all stamping imperfections are removed in the operation. After the stampings have been run hot and allowed to cool off, they are re-run through the die with irons added to the die to sharpen all corners and to set beads, and also to take out shrinkage caused by the cooling of the stampings.

It has been found very desirable to combine the use of hot and cold stamping in the same job, making the more difficult stampings, such as the steel shells seen in Fig. 5, by the hot process, which eliminates finishing and the possibility of extensive breakage that would occur if the stampings were made cold.

Quality Results from Long Experience

Quality in hot stampings of fenders, dust aprons, radiator splashers and body panels for high-class automobiles is the result of many years of experience in producing metal stampings of the most intricate design and difficult character. For more than half a century the company with which I am connected has fabricated metal statuary, including statues of famous men and soldiers with all of their trappings which today stand in public squares throughout the Country. The famous Diana, that for years crowned the tower of Madison Square Garden and was admired by persons from every land, and the Quadriga located on the Wayne County Building in Detroit, are evidences of the artistry of our workmen. There are many others well known to the American public, such as the group on the New York Life Insurance Building, the revolving statue atop the Montgomery Ward Co. Building and the Flying Dutchman, the famous trademark of the Moline Plow Co. that was first shown to the public at the Chicago World's Fair in 1893. Some of these statues reach a height of 36 ft. and are made of metal stampings skilfully wrought and so carefully put together that the finished work has the appearance of solid bronze.

With the advent of the automobile, it was natural to divert the skill of the hot-stamping artisans to automotive sheet-metal work. The Pope-Toledo Co. was among the first to take advantage of the experience in metal stamping, and it was at the Mullins plant that the bodies for many of the pioneer cars were made. As new automobile companies started production, many followed the example of the pioneers, and the continued and increasing use of stamped metal by leading manufacturers is a tribute to the artisans in metal, who are now directing their efforts to the production of perfectly fitting steel-stampings.

AIRCRAFT CARRIERS

THE trouble of landing aircraft on board a moving ship will always be a very serious one, but the problem appears to be solved as well as possible. Experiments have been carried out in the slow aircraft-carrier Langley, whose smoke-stacks are hinged and fitted with cooling devices; the results of these experiments are presumably to be seen in the big single funnel of the Lexington.

Experience with the old converted Cunard-Liner Campania with the Grand Fleet during the war proved that an aircraft carrier should have at least 3 knots in hand over and above the speed of the squadron with which she is expected to work. Steaming at high speed the diversions of course and maneuvers necessary for an aircraft carrier were found to bring her right astern of the fleet. This lag should be reduced in the case of the Lexington, which is provided with two 60-ft. training compressed air catapults, one on either bow. The fastest American capital-ships have a speed of 21 knots, so that the Lexington's 33¼ will be very ample for squadron purposes, and suggests that she and her sister, the Saratoga, have been converted very largely with an eye to detached operations in distant waters, especially in the vast distances of the Pacific.

The early designers of aircraft carriers were confronted with the great danger of fire on account of gasoline fumes, and in the experiments carried out in the British Navy before the war careful measures were taken to stow all the fuel in 2-gal. tins on the upper deck. When the Hermes was torpedoed this was the factor that saved all her survivors, but it is, of course, very impracticable in the modern carriers that transport a large number of machines. In the case of the Lexington it is understood that a particularly large and elaborate system of piping has been installed, so that the gasoline can be stowed in bulk in a protected position as low down as possible and can be pumped to a number of filling stations that are located in different parts of the ship.

In size the Lexington is so much bigger than any European aircraft-carrier that she is most fairly comparable with the Japanese Akagi of some 33,000 tons and a speed of 33 knots. She also was laid down as a battle cruiser, of the improved Kongo type, and converted under the Washington Agreement. She was launched before the Lexington, preliminary experiments being carried out in the 9000-ton Hosho, and she has been reported to have been none too satisfactory. With their ability to carry large numbers of aircraft, to steam at high speed right across the Pacific and back again without refueling, and to protect themselves from any marauding man-of-war that they are not able to steam away from, these two ships are both capable of destructive air raids.—*Engineering* (London).

Fundamental Requirements for Commercial Aviation

By W. B. Stout[1]

Aeronautic Meeting Paper

ABSTRACT

DEFINING a commercial airplane as one that "can support itself in the air financially as well as physically," the author states that when, how and where a plane is used determine whether or not it is a commercial plane. Although some of the old "Jennies" left over from the war have been used with profit in certain narrowly restricted lines of work and the planes used in the Air Mail Service may be regarded as commercial planes, in a sense, the real commercial airplane is one that can earn the greatest dividend under the widest range of conditions. The two fundamentals to be met are the accomplishment of the most ton-miles per horsepower and the most hours per day in the air.

Safety and reliability are essential to the earning of dividends, and the operation of the planes in the air must be supported by an active business organization that will secure sufficient traffic to keep the planes loaded and by a ground organization for the proper maintenance and inspection of the machines.

Two major requirements that must be met before we can have true commercial aviation are a real airplane engine, air cooled, and absolutely dependable navigation apparatus, preferably a radio system. Eventually, planes must be of metal, as high insurance rates will preclude the use of any other kind, particularly for passenger transportation. Large cubic capacity is of prime importance for passenger and express work. Passenger cabins must be roomy but need not have high roofs that will permit of standing up and walking about.

Six requirements for the successful airplane of the future are listed, and, after discussing the type of powerplant needed for airplanes, the author deals with the choice of airplane routes. The highest development of air service will be in intercity passenger and express work, with planes operated at night. At the lower end of the scale will be lines between small remote communities with planes operating in competition with dog teams, pack animals and canoes in territory that is too rugged or otherwise impracticable for other means of quick transportation.

Data on the operation of the Ford airlines between Detroit and Chicago and Detroit and Cleveland during the first six months of service are given, including the carrying of a complete Ford automobile, with body, to Cleveland. The plane used gives excellent service over level terrain but is not adapted for work over mountainous country; such work requires planes with three or more engines to enable them to continue with load even if one of the engines goes dead. A commercial plane must have the same degree of lightness as a military plane but must be more rugged to assure longer life and to keep down the cost of maintenance. Aviation laws and a sufficiency of landing fields cannot bring commercial aviation until we have commercial airplanes.

OPERATION of aircraft commercially is a new undertaking in America but is built up on the well-known fundamentals of other established transportation services.

The first fundamental of commercial air operation is a commercial airplane. A commercial airplane is an air vehicle that *can support itself in the air financially as well as physically.*

This definition raises many questions as to just what is meant; one at once visualizes long airlines and short routes, lines in competition with railroads in densely populated areas and lines operating over terrain that is impossible to other means of transportation. These questions, however, only emphasize the fact that whether an airplane is commercial or not is determined largely by when, how and where it is used.

While planes built for air-mail use may be classed as commercial planes, in a sense, since they are able to earn a profit in specialized work, the service is very different from that which actual commercial operation will demand. A very few men have succeeded even in making commercial planes out of the old "Jennies" left over from the war, and actually have made money with them in certain narrowly restricted lines of work. Others have accomplished commercial work at a profit with seaplanes and flying boats, but also in greatly restricted services and under unusual conditions. Despite these facts, one hardly can call the JN-4 or one of the old flying boats a commercial plane, for it can make money only in exceptional cases.

That plane is the most commercial that can earn the greatest dividend under the widest range of conditions.

What the Commercial Plane Must Accomplish

There are two real fundamental capabilities that a commercial airplane must have: (*a*) the ability to accomplish the most ton-miles per horsepower, and (*b*) the ability to stay in the air the most hours per day. The first includes all of the factors of design that make for performance and which, in most planes, have been made paramount. The second embraces that part of design which relates to cost of maintenance, both in man-hours and in cost of material and overhead. The best commercial plane, therefore, is the one that will accomplish in the air the most ton-miles per dollar per day.

In assuming, in connection with the plane, a business system and a maintenance and inspection routine that are necessary to obtain the foregoing result, it is seen at once that the business and physical organization surrounding the airplane in its work is next in importance to the airplane itself. A plane cannot perform a maximum number of ton-miles per day unless a traffic department secures business enough to keep the plane full to capacity on every trip. Yet it is of no use to have full loads on every trip unless design, maintenance and inspection have put, and keep, the ship in a condition that will enable it to stay in the air for the length of its prescribed route on every trip that is made.

This last statement indicates, as a side thought, that safety also is a basic condition of airline operation. *If a line is not safe and reliable it certainly cannot earn a dividend,* and any airplane that is not safe under even

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extreme conditions cannot be called a commercial plane. It is the belief of our organization that eventually planes must be of metal; that insurance rates will make impossible the use of any other type, particularly for passenger transportation.

What Is Required of Commercial Planes

That you may know what I have in mind as a commercial airplane, and I may say that no one has produced it yet, I will list what may be expected of a plane within 3 or 4 years.

(1) Absolute reliability of structure under all conditions of weather or fire hazard
(2) Absolute dependability of powerplant, accomplished possibly by multiple engines
(3) A speed of 100 m.p.h., with full load, in horizontal flight at sea level, on not more than 3/5 of the maximum horsepower
(4) Pilot located forward to assure unobstructed vision when planes become common over air routes, particularly in bad weather
(5) A pay load of at least 4 lb. per hp., with fuel for 6 hr. of flight
(6) *Ability to operate 20 hr. per day in the air with load*

As these requirements are considered, it will be seen what type of organization would need to be built around such a plane and the types of routes that would be necessary to make it a success.

Two major requirements must be met before we can have real commercial aviation or commercial airlines. The first is a real airplane engine, by all means air-cooled and without electric ignition, if possible. The second is absolutely dependable navigation apparatus, probably a specially developed radio system. Such a commercial airplane and equipment do not exist today but we all know they are in sight and not more than 18 months away. How quickly they will come into use will depend upon the amount of money and intelligence we Americans are willing to utilize in the next few years to produce the results.

Cubic capacity is important in commercial express or passenger work. For passenger transportation the cabins must be roomy, perhaps reproducing for aviation the low-roofed motorcoach body rather than the high-ceilinged street-car body in which one can stand and walk around. A cubic capacity of only 30 to 60 ft., as in air-mail ships, will not suffice for merchandise routes, and certainly not for passengers.

Operation of the Ford Airlines

Some information from our experience in operating all-metal Liberty-engined planes over the Ford Motor Co. routes from Detroit to Chicago and from Detroit to Cleveland should be of interest.

We are now in the sixth month of operation, flying daily, except Sunday, over a 260-mile course to Chicago and return, and 127 miles to Cleveland and return, a total of 774 miles per day. We, therefore, have totalled about 8 hr. per day in the air during this period, flying more than 120,000 miles and carrying, all told, more than 300,000 lb. of merchandise, without any loss and with greater regularity than that of the railroad service.

Our cabin has 280 cu. ft. capacity. Most of the time the floor is covered with boxes and bags of forgings and parts needed for production. At other times planes arrive at Dearborn with bales of curled hair or great piles of cardboard boxes containing Lincoln automobile headlights, which completely fill the cabin and, later, the Ford truck that is waiting to receive the load. It will be seen that cubic capacity is necessary.

Our loads vary from 1000 to 1500 lb. per trip, with an average of about 1200 lb., in addition to 150 gal. of fuel, 14 gal. of oil and often an extra pilot in training. On one occasion the plane was flown to Cleveland with a complete Ford car, body and all. Our friend, Glenn L. Martin, told me that the newspaper announcement of the plan sounded so suspicious that he sent a man out to the field to check up and see if everything was there. It was. Within 51 min. after the plane had landed in Cleveland the assembled car was ready to drive away. That load weighed 1412 lb., complete, and most of the trip was made with the engine turning at 1450 r.p.m.

Record of Operating Cost

Data on the cost of operating the service to Chicago and Cleveland, which was started with one plane but is now carried on with nine planes, have been taken from the Ford Motor Co. cost sheets and are given in Table 1.

TABLE 1—OPERATING DATA ON FORD AIRLINES TO AUG, 1, 1925

Dearborn, Mich., to Chicago Service

Plane No.	Round Trips	Goods Carried, Lb.	Miles	Cost
1	52	101,268	26,530	$8,924.91
2	31	60,025	15,810	5,845.18
3	4	8,385	2,040	787.01
	87	169,678	44,380	$15,557.10
Load per Single Trip, Lb.				975
Cost per Single Trip				$89.410
Cost per Mile				0.350
Cost per Pound				0.092

Dearborn, Mich., to Cleveland Service

Plane No.	Round Trips	Goods Carried, Lb.	Miles	Cost
1	11	19,182	2,794	$1,033.06
2	8	13,460	2,032	721.31
3	7	12,131	1,778	776.06
4	1	1,894	254	561.39
	27	46,667	6,858	$3,091.02
Load per Single Trip, Lb.				864
Cost per Single Trip				$57.250
Cost per Mile				0.450
Cost per Pound				0.066

Total Service

Plane No.	Round Trips	Goods Carried, Lb.	Miles	Cost
1	63	120,450	29,324	$9,957.97
2	39	73,485	17,842	6,566.49
3	11	20,516	3,818	1,563.07
4	1	1,894	254	561.39
	114	216,345	51,238	$18,648.92
Load per Single Trip, Lb.				944
Cost per Single Trip				$81.790
Cost per Mile				0.360
Cost per Pound				0.086

The figures relate to four planes and cover the period of operation from the start of the service up to the end of July, 1925. The totals show that the average load per trip for 228 single, or one-way, trips was 945 lb., the average cost per single trip was $81.79, the average cost per mile was 36 cents and the average cost per pound carried was 8.6 cents.

For the first 3 months of operation our actual average speed between Detroit and Chicago, with loads, was 96 m.p.h, but during the next 2 months, after bad weather had set in, this average dropped to 93 m.p.h., because most of the winds encountered were crosswise of the

course. Another speed handicap was that the ships flying to Chicago, leaving at 12 m., traveled against a wind that the plane did not have in its favor coming back, since the summer wind dies down about 5 p. m. and the ship is not due at Ford Airport until 6:30 p. m.

As this work is being done with an ordinary Liberty engine turning at normal engine speed, we believe the record is rather remarkable, particularly the fact that we have had but one dead-stick landing during the whole period of operation. Trips were made with as much as 2700 lb. of useful load.

Although this plane has proved to be excellent in service over level terrain, it is not adapted for work over mountains or hilly country where landing fields are not to be had or where unusual weather conditions require the pilot to go above storms out of sight of the ground. Such work can be done only by planes having three or more engines so that they can continue in flight with full load for a long period even though one of the engines may go dead.

Planes Must Be Kept in the Air

Flying equipment standing on the ground is a liability, like a motor truck standing still or an ocean steamship at the dock. It earns its pay by ton-mile service and must be in the air the greatest possible number of hours per day. The airplanes used in the Air Mail Service have been small and were turned over to the Post-office Department by the Army. Each pilot has had his own plane, therefore, from three to five planes were on the ground for each one in the air. It should not be necessary, in commercial airline work, to have more than one plane on the ground for two in the air, and even this ratio can be bettered. This will be possible, however, only when powerplants and other devices are interchangeable, so that operators can change any defective equipment almost immediately and get the machines back into the air promptly.

The major difference between a military and a commercial airplane is in the length of life. The average military ship does not spend more than 5 or 6 hr. a week in the air, hence flimsy construction is allowable. The same degree of lightness must be maintained in a commercial ship but the strength factor must be much greater to save maintenance cost. It is easy for us to design a plane that will give better performance than our present commercial ship, but not one with the ruggedness that is necessary in every-day all-weather commercial operation.

Constructors Turning to Air-Cooled Engines

Second in importance only to the structure of the plane itself is the powerplant. We have been using modified automobile engines in our so-called commercial planes up to the present, but the real airplane engine is still to be built. It is quite certain that it will not be of the present automobile type.

One-half pound of weight can be saved in the plane for every pound saved in the engine, making a total saving of 1½ lb., or 30 cents per hour advantage. Commercial planes, however, must be able to carry fuel for at least 5 hr. for normal work in America, hence low consumption is as important as low engine-weight, because it is necessary to reduce to the minimum the weight of the fuel carried.

It is as great a mistake to water-cool an airplane engine for commercial work as it would be to air-cool a motorboat engine. Better airplane performance with air-cooled engines is only a matter of learning how to reduce the head resistance of air-cooled jobs. Even today, air-cooled engines have proved their superiority for this class of work and, so far as I know, every new airplane projected in America, with the exception of one, is air-cooled.

These new engines must have from 300 to 500 hr. of life between top overhauls and yet must be so simple and the parts so accessible that two men can overhaul an engine completely over night and have it ready for test flight by morning. With the 18-hr.-per-day service that is soon to come in airline work, this will be necessary in order to keep the equipment in the air.

Aviation laws and a sufficiency of landing fields cannot bring commercial aviation until we have commercial planes. Once the right type of machine is available, however, the ground organization becomes of even more importance than the machine. The organization for servicing the planes must concern itself mainly with engines, for the engine is almost the only part that is subject to wear. Systems of engine inspection, replacement, testing, and repair, are too well known to need discussion before automotive engineers, but our increasing experience indicates that the more the powerplants can be constructed in a series of complete minor assemblies so that in case of trouble these assemblies can be replaced quickly, the better the design will be. It will not pay to make an airplane engine heavier so that it will have longer life. To add 100 lb. to an engine is to take 200 lb. per day off of the revenue-producing capacity of the plane, which is an amount that will pay for considerable ground work and servicing.

Kind of Air Service To Come

Consideration of the airline to be operated ranks next in importance to the airplane and its powerplant. There are places where one can run a "steamboat line" with a rowboat and an Evinrude engine and make money, but the Leviathan could not pay a dividend in the same place. In the same way, there are unusual services in which a two-seater plane can make a profit but in which a 1000-hp. airplane probably would be worthless. *Planes must be suited for the work and the work to the planes.*

The future of aviation does not lie in selling thrills to the public but in carrying loads from place to place in the service of industry. The joy-ride business has done much to convince the public of the dangers of aviation, so those who are working commercially have a real prejudice to overcome in the minds of the public before they can start passenger work seriously. Most airlines so far have been promoted with the speed of the airplane as an asset. Speed is not the most important advantage possessed by the airplane, although it is important. The greatest accomplishment of flying is the covering of terrain that is impassable to other means of transportation.

Both speed lines and lines over rugged or forbidding terrain will be feasible with ships designed for the particular purposes. There will be lines between our great civic centers in competitive operation with railroads. Most of these will operate at night, with high-speed ships and a high tariff rate. Eventually the ships will be high-pressure-service clearing ships operating under high tension for reliability of schedule. This service will be the most highly organized.

At the opposite end of the scale will be planes operating between remote communities in competition with dog teams or canoe transportation over terrain where railroads or even highways are impossible, and where boats of any kind cannot be used on the waterways be-

cause of falls and rapids. These planes can be geared for low power and operated with very little overhead expense, and will pay dividends because of their ability to pass over mountains, deserts and valleys rather than because of high speed.

North America Ideal for Airlines

North America, including Canada and Alaska, is an ideal country for airline operation. In the United States, and particularly in the East, we shall be concerned with lines of a high-speed intercity type. In the West, among the mountains, and in Canada and Alaska, the airplane is destined to be the greatest mechanical missionary that has ever been used. This might also be said to Mexico and South America. Mountain flying, unfortunately, involves navigation in fogs and other bad-weather conditions, so, while flying equipment for the work already is feasible, we are still waiting for navigation aids to make such flying safer to both the operating personnel and the passengers.

The location of an airline has considerable to do with its profit possibilities. The ideal airline covers a triangular route, with planes flying in opposite directions. This requires but one landing field in each city for planes flying to two cities in different directions and therefore cuts down the overhead, or ground organization, cost in a way that is impossible with a line operated between only two cities in which a terminal landing field is required in each.

It is very important, of course, to keep down the overhead. Every landing field means cost, not only for the property but for ground crew, maintenance station and other items of expense that decrease dividends. All of these items should be considered in making a survey before the line is started. Maintenance and the development of systems for inspection and building up the morale and tradition of an organization, however, can be learned only by actual flying and the operation of a commercial airline.

Air travel is coming, and will come at a rate that is scarcely anticipated even by those in the airplane industry. A veritable avalanche of airline development is almost upon us, and those who are wise will prepare for it.

WORLD PETROLEUM PRODUCTION

THE world's production of petroleum in 1925 is estimated at 1,058,000,000 bbl., or only about 4½ per cent greater than in 1924; the yearly production in the last 3 years has averaged close to 1,030,000,000 bbl., the output in this time remaining, therefore, practically stationary. The production in the United States in 1925 is estimated at 755,000,000 bbl., or forty-odd million barrels over 1924, this increase corresponding very closely, numerically, to the over-all increase of the world's production in the same period; and if we attribute the gain in the world's production in 1925 to the increased yield of the United States, it follows that the aggregate production from fields other than the United States has remained practically stationary in the year.

The United States has easily retained its leading position, yielding 71.4 per cent of the total, the daily output in 1925 being not much over the average for the last 3 years, or somewhat over 2,000,000 bbl.; this condition being in sharp contrast to that of the years previous to 1923. The output toward the end was but little in excess of that at the beginning of 1925, and it is expected that this condition will not materially change in the near future.

The outstanding developments in the other producing regions have been the sharp decline of production in the Mexican fields; the rapid increase in Venezuela, which more than doubled the yield of the preceding year; and the important, although less spectacular, increases in Russia, Persia, Rumania and Peru. The Mexican decline, aggregating 26,000,000 bbl., or about 19 per cent, has been due to the flooding and exhaustion of producing areas and the lack of discovery of important new fields. The daily production averaged about 390,000 bbl. in the year, which represents about 10.6 per cent of the world's total. It will be seen that the combined production of the United States and Mexico accounts for 82 per cent of the world's output in a year of ordinary production.

Although the statistics are incomplete, it is evident that a marked improvement has been made in the production of the Russian fields, which is estimated to have increased about 22 per cent, the average daily yield being over 150,000 bbl., representing over 5 per cent of the total production of the world. The increase in production of the Persian fields has been consistent with its past history and the systematic manner in which development has been carried on and production regulated in accordance with market requirements; the output here increased approximately 17.0 per cent, the daily figures being close to 96,000 bbl., or 3.3 per cent of the over-all total. The fields of the Dutch East Indies showed a moderate increase of 2,000,000 or 3,000,000 bbl., in line with previous producing history, the daily average production being close to 60,000 bbl., or about 2 per cent of the grand total. The rapid increase in the Venezuelan production has been the result of a fairly uniform yield during the year at the high rate reached at the close of 1924. The output increased from 9,000,000 to 19,000,000 bbl., or over 100 per cent; and as a result Venezuela has now displaced Rumania and ranks sixth in the world's producing regions. The daily output of the fields averages about 52,000 bbl., representing 1.8 per cent of the world's total. The yield of the Rumanian fields reached in 1925 the peak figure of 15,000,000 bbl., which is about 2,000,000 bbl. in excess of the previous year and represents the largest production at any time during the long history of these fields. The actual figures, therefore, are not as important as the fact that Rumania, perhaps the oldest producing country, has reached its highest production after many fluctuations since 1857. The fields produced an average of 41,000 bbl. daily, representing about 1.4 per cent of the world's output. The production of Peru increased from about 7,500,000 to 11,000,000 bbl., or about 26 per cent; and the country, which has been producing since 1896, reached a new maximum in the present year, with promises of greater yields in the future. The daily production is close to 30,000 bbl., representing 1 per cent of the grand total.

The fields of India remained practically stationary with a slight downward tendency. Poland, Argentina and Sarawak or North Borneo showed an increased output, while the other miscellaneous fields showed slight gains or nominal losses.

The United States and Mexico should, for some years to come, retain the control in the world's petroleum industry, and it is on the stability of their combined production that the stability of the world's petroleum industry should rest. The estimates of oil reserves in the United States, as calculated by Government experts, are represented by figures around 9,000,000 bbl., and these reserves would be theoretically exhausted, at the present rate of production, by 1935; and, although it is obvious that actual conditions will not conform to these estimates or conclusions, these factors do represent the best guess of a group of very highly trained, efficient and impartial engineers, and as such are worthy of serious consideration.—V. R. Garfias, H. L. Doherty & Co.

Discussion of Papers at the Semi-Annual Meeting

THE discussion of six of the papers presented at the 1925 Semi-Annual Meeting held at White Sulphur Springs, W. Va., June 16 to 19, is printed herewith. The authors were afforded opportunity to submit written replies to points made in the discussion of their papers, and the various discussers were given an opportunity to approve the stenographic report of their remarks before publication. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with the minimum of effort.

OIL-FLOW IN COMPLETE JOURNAL BEARINGS

BY D. P. BARNARD, 4TH[1]

ABSTRACT

GENERAL laws governing the rate of flow of oil through complete journal bearings are developed in the paper. These laws are based on the assumption that axial flow obeys Poiseuille's Law and is, therefore, a function of the bearing load. Dimensional reasoning indicates that the volumetric efficiency of a bearing considered as a pump is given by an equation of a form in which efficiency equals a function of the viscosity times the rubbing speed divided by the bearing load, the length divided by the clearance and the length divided by the diameter. Experimental evidence is presented which substantiates this point of view.

The general relation of rubbing speed to heat generation and oil-flow is discussed for the purpose of indicating a possible solution of certain high-speed-bearing problems. A plain bearing is, in effect, a pump in which the flow of a viscous lubricant through a passage of varying area develops a pressure sufficient to sustain the imposed load. Oil-flow in the direction of the axis of such a bearing is due to two causes: oil-film pressure developed to support the bearing load and oil-feed pressure. The oil-flow due to the first of these causes, or the efficiency of the bearing as a pump, is the important factor. The influence of both sources of pressure is considered separately, and the seven conclusions reached are stated.—[Printed in the August 1925 issue of THE JOURNAL.]

THE DISCUSSION

G. B. UPTON[2]:—The term "pump efficiency" of a bearing, as used by Mr. Barnard, may perhaps be misleading. In the mathematical ideal bearing so often investigated there is no end-leakage of oil. The clearance of the bearing is filled once for all with a quantity of oil, the volume of the clearance space is non-variant, and this same oil circulates around indefinitely as the shaft turns. The "pump efficiency" of such a bearing would always be zero, for no oil is lost or added, yet all running conditions, from metal contact to concentric running of the shaft in the bearing, might occur.

End-leakage does always occur to some extent in an actual bearing. The viscous drags that tend to carry the oil circumferentially around the shaft increase with the ZN product and are opposed by the P, or load forces which tend to squeeze oil out endwise in the loaded half, mainly, of such a bearing as was tested by Mr. Barnard. This is all there is to end-leakage in the case of zero pressure in the oil-feed lines. When pressure is put in the oil feed, there is end-leakage due to this pressure, and this leakage occurs mostly on the unloaded half of the bearing. The end-leakage on the loaded half of a bearing should be little affected by pressure in the oil-feed lines.

When the ZN product goes toward zero, or P becomes too high, the minimum oil-film thickness approaches zero or the film breaks. In this case there is no circulation of oil around the shaft, and the "pump efficiency" of the bearing goes up to 100 per cent or more. When $(ZN)/P$ increases and the oil-film on the loaded side becomes thicker, the "pump efficiency" falls; indeed, one may almost say that the thickness of the oil-film toward the load, between shaft and bearing, is an inverse function of Mr. Barnard's "pump efficiency." In this sense the only dangerous case would be that in which the "pump efficiency" was high.

The term and what it stands for have practical application exactly as Mr. Barnard discloses, that is, in figuring the rate of change of oil in the bearing, or its passage through the bearing, hence the ability of the oil itself to carry away from the bearing the heat generated in the oil-film as the oil performs its duty.

Since the eccentricity at which a shaft runs in its bearing decreases with the $(ZN)/P$ ratio, the rate of heat generation in the oil-film does not increase as fast as the square of the speed. A further factor is that viscosity itself drops as the temperature rises. The combined effect of this drop and the change of eccentricity with $(ZN)/P$ may bring the rate of heat generation in some cases even toward the first power of speed.

In pressure-feed lubricating systems this study of Mr. Barnard's gives an added reason for running the oil-feed pump without a spring-loaded valve limiting the pressures in the oil-feed lines, as Mr. MacCoull has proposed on other grounds. Mr. MacCoull showed the desirability of letting the oil-line pressure go up as high as it would in the case of a cold engine, where Z is high. Mr. Barnard shows that the oil-line pressure should go up as high as it will with increase of the engine speed N, in order to keep the oil circulating through the bearings for cooling purposes at least on the increase as N increases.

D. P. BARNARD, 4TH:—The term "pumping efficiency"

[1] M.S.A.E.—Research engineer, Standard Oil Co. of Indiana, Whiting, Ind.
[2] M.S.A.E.—Professor experimental engineering, Cornell University, Ithaca, N. Y.

was employed in preference to "end-leakage" because of the implication of the latter that such oil-flow constitutes a defect which should be eliminated; while, in fact, it may be frequently necessary to adopt methods for its increase. It is true that the tendency for all oils to drop in viscosity with increasing temperature is most effective in preventing the too-rapid generation of frictional heat; however, particularly in high-speed machines, the possibility of keeping bearing temperatures substantially constant through forced increase in pumping efficiency should not be overlooked. As Dr. Dickinson points out, it is necessary in most instances to effect a compromise which will assure a value of $(ZN)/P$ high enough to guarantee sufficient carrying-power, and at the same time small enough to permit of an adequate flow of oil through the bearings.

TRANSMISSION NOISES AND THEIR REMEDIES

BY EARLE BUCKINGHAM[3]

ABSTRACT

DISCORDANT sounds from transmission gears can be avoided by using gear-tooth ratios that give pleasing combinations of tones; a 5:6 ratio produces a minor third note; a 4:5 ratio, a major third; a 2:3 ratio, a perfect fifth and a 2:1 ratio, an octave. Careful attention to selection of relative tooth-numbers, therefore, will aid greatly in the production of quiet or unobjectionable transmissions.

Careful design and accuracy in the production of gears will not, alone, insure quiet operation; the shafts must be sufficiently rigid to hold the gears in proper operating position and large flat surfaces in transmission cases, which act as sound amplifiers, should be avoided. Bearings may also be noisy through faults of their own or because of improper mounting and alignment. Too much lubricant in the transmission case may be another cause of noise; the practice of filling the case full does more harm than good, although the large quantity of oil may serve to absorb the vibrations of the case. Sufficient space should be left for the excess oil to be squeezed out from between the gear teeth readily, as heat generated by forcing the oil out suddenly raises the temperature in the transmission case to a dangerous degree if the faces of the gears are wide, as in motor trucks.

Four characteristic sounds are produced by the gears. One is an intermittent clicking or irregular growl caused by poor spacing or irregular profiles of the teeth; another is a pulsating growl caused by eccentricity; a third is a high-pitched squeal due to rough tooth-surfaces and a fourth is a tone that depends on the pitch of the teeth and speed of the gears. The remedy for the first three is accuracy in tooth generation and better workmanship; that for the fourth is to select a gear ratio that will produce a musical note.

Some sound is inevitable when power is transmitted through gears; the search for some modification of tooth profile that will obviate the need for accuracy has been fruitless and probably always will be, as the spacing between the teeth must be nearly perfect to assure quiet running. A solution of the noise problem that may be satisfactory today may not be satisfactory next year; other parts of the automobile have been made quieter and as a result the sounds from the transmission, which were not noticeable before, have become objectionable. Three courses are open to remedy the noisiness; (*a*) eliminate the gears, (*b*) reduce the amount of noise produced by them and (*c*) change the quality of the sounds so that they will not be annoying. [Printed in the July, 1925, issue of THE JOURNAL.]

THE DISCUSSION

SAMUEL O. WHITE[4]:—Although elimination of the gears has not been accomplished in a practical, commercial way, a great amount of work has been done and we, as gear manufacturers, are alert regarding further developments. Naturally, however, we feel that our principal interest lies in geared designs.

The suggestion to reduce the actual noise of the gear teeth by methods of gear cutting is one on which every manufacturer has worked for years; much progress has been made, particularly by the gear specialist who could devote his efforts exclusively to those peculiar problems. Special tooth-forms have shown no improvement over the involute form, except that slight modifications of the theoretical involute are sometimes of value. The modifications are very slight indeed, moving over a portion of the tooth curve only a few thousandths of an inch. Accuracy and uniformity are the essentials of a reasonably quiet gear-drive in a modern automobile-transmission and to a degree not dreamed of a few years ago. The variations of outline from tooth to tooth and from gear to gear must be kept within limits measured in tenths of thousandths of an inch. Instruments capable of checking to such fine limits have been available only within recent years, and no one instrument will check all the necessary elements. The accuracy necessary in the gears reflects back to still greater accuracy and rigidity of gear-cutting machinery and cutters to such an extent that the manufacturers of such machinery are not able to keep up with the quality demands made upon them by the transmission manufacturer who, in turn, is constantly being pushed by the industry to approach nearer and nearer to a quiet transmission in large commercial quantities.

No known self-operative method or machine exists today for producing quality gears. Infinite and almost unbelievable care and pains on the part of operators, inspectors and supervisors are required to maintain the product at the high standard now required. The gears will vary from day to day with slight variations in the steel, in its forging heats, in the preliminary heat-treatment, in the cutting compound, in the weather, in the health and mental condition of the men, in the cutters, in the cutter grinding, in the machines—which must be constantly checked, maintained in correct adjustment and kept tight—and in the use of the inspection and checking devices, which are subject to the variations of the personal element in the interpretation of their readings.

The distortion of teeth from heat-treatment is not so great as was formerly thought, especially with oil-hardening steel, handled in electric heat-treating furnaces and when using stub teeth. Standard full-depth teeth may be a little better in the "green," but seem to distort more in the fire due to their length and their thin tops. Our experience indicates that we can cut gears in large production-runs that will be just as quiet as gears ground after hardening. The chief function of the gear-

[3] M.S.A.E.—Engineer, Niles, Bement, Pond Co., New York City.
[4] M.S.A.E.—Chief engineer, Warner Gear Co., Muncie, Ind.

tooth grinder, as developed up to the present, seems to be that of salvaging that proportion of the gears which has not been properly cut originally or which has been distorted unduly in the fire. The tendency of the grinding wheel, moreover, is to follow the errors in form and spacing already existent. Further, the difficulties in the way of keeping the gear-tooth grinder and its wheel adjusted and tuned up to function accurately in continuous production are even greater than the similar difficulties on gear-cutting machinery, and involve the variable human element to just as great a degree. In short, we agree with Mr. Buckingham that high-class workmanship, such as few shops can provide, is as essential as correct design, and perhaps more essential.

Referring to the suggestion to change the quality of the tone to make it less objectionable, much experimental work has been done and many interesting theories in harmonics have been worked out. Some of this is encouraging and progress has been made, but results thus far often are conflicting and so many other conditions enter that this is far from being an exact science as yet. One of these conditions is that the vibration period of the car may bear such a relation to that of the transmission as to make the noise either worse or better than it was when tested on a solidly mounted transmission-testing block; also, that the period of the transmission as a whole may make worse or better the noise of any set of gears, when considered alone.

Mr. Buckingham has indicated some conditions that avoid resonance, in all of which he is correct. Heavy sections in the gears and uniform sections to secure minimum distortion in the heat-treatment, heavy wall-sections, and irregular and well braced walls, all lessen the resonance. Iron is much preferable to aluminum. All moving parts should be fitted as close as will allow them to operate successfully, to minimize the opportunity for rattle.

Another suggestion might be added to those in the paper, this being the possibility of absorbing the sound. Acoustical engineers have shown that poor acoustics of a public auditorium is not due to faulty architecture to the extent that was formerly believed, so much as to the ratio between the area of the hard reflecting surfaces of the room and its volume. It is now an everyday experience to correct scientifically any acoustically defective room by sound-absorbing panels of felt and canvas properly applied to the walls and to the ceiling. It is easy to overdo such practice and ruin the room for music.

This practice suggested to us a similar treatment of transmission cases, and much experimental work has been done in this direction. While no commercial solution has been developed, some encouragement exists for further efforts to discover a practical and inexpensive sound-absorbing material to attach to, or to be built into, the case walls. A further suggestion would be to line the under side of all the body floors with some sound-absorbing material such as Celotex. This is an inexpensive, light fibrous, cellular building-material, similar to wall board but about ½ in. thick, used in building construction for insulating walls and floors. It absorbs some of the sound and relieves the passengers to some extent, particularly in closed cars.

The points brought out in the paper in regard to the part played by oil are very valuable. Each transmission design has its own best oil-level, and there will be more noise either above or below that level. The proper level should be determined by careful experimentation with fluid oils. The situation is changed if an attempt is made to use heavy compounds or greases, which, by the way, are not very satisfactory transmission-lubricants.

It may not be generally realized to what an extent the oil itself makes a noise, which sounds much like gear noise, and that it may be more difficult to eliminate. This is partly a snapping sound due to the viscosity of the lubricant, which is being constantly whipped and stirred, also the slapping impact of the gear teeth into oil, like that of the paddles of a paddle wheel, and the impact of the particles of oil being thrown against the walls and other parts of the transmission. This results in a very metallic sound which may be called "oil swish." Lighter oils run more silently than heavier oils; it is therefore desirable to have a deep enough case to provide plenty of oil at the bottom, and to have the case walls not too near the gears.

The latter part of Mr. Buckingham's paper touches on a situation which is even more troublesome than gear noise, because it affects the design of the entire chassis, and there is such a divergence of opinion as to the real causes and their remedies that it is difficult for engineers to agree on them. It is a subject that we approach with some hesitancy, as we may have the appearance of trying to prove an alibi. However, it is a proved fact that external elements are the cause of most of the transmission noise, heard usually when using direct drive at rather fast road-speeds, and of a portion of the noise when in gear, but using a fast engine-speed. The noise is actually made in the transmission by vibrations coming from other parts. Hence, a closely fitted transmission will rattle or chatter less than a loose one, and it is the transmission manufacturers' problem to produce transmissions with the minimum of loose parts to rattle, and to make the necessary moving parts as close fitting as practicable. However, there must be enough backlash in the gears to admit a film of oil and accommodate some of the inaccuracies of manufacture; likewise, the bearings and bushings cannot be tight, sliding gears must be loose enough to slide and the direct-drive clutch free enough to engage, all of which produces a necessary total backlash, or play, which permits an annoying rattle when vibrated by external causes. The transmission is to these what the violin body is to its strings. Vibrations coming from either end of the chassis head up in the transmission and are there amplified and given out as a greatly increased volume of sound.

The first of these outside causes is the engine. Every engine has a periodic vibration and about all that can be done for it seems to be to balance it as nearly as possible and provide a sufficiently stiff and heavy crankshaft and a heavy flywheel. Some designs have gone too far in lightening the flywheel, especially. Increasing the length of stroke increases vibration difficulties. The next offender is the clutch, particularly those types in which the driven member has to be free enough on the shank of the main drive-gear to slide. This should be as close a fit as is feasible. Some form of flexible connection between the engine and the transmission is highly desirable, and one form of flexible disc built into the clutch has been found most effective in absorbing the engine vibrations and thus quieting the transmission.

One cause of vibration is almost a part of the transmission, being the pressed-steel brake-drum mounted for the transmission brake. This drum is rarely round and, even if trued-up, goes out of shape the first time it becomes hot in service. The transmission brake-drum should be a casting, carefully trued-up and balanced, and sufficiently heavy to have some flywheel action to assist in smoothing out the vibration and to absorb and radiate the heat without distortion.

Behind the brake drum we have universal-joints and a propeller-shaft. There should be the minimum of play in the joints and the drive should be as nearly as possible in a straight line to avoid irregular universal-joint action. The propeller-shaft is almost as serious an offender as the engine. It should be of more generous diameter and section than is usual in most cars, and should be in accurate running-balance, together with the joints, to avoid any tendency to whip or vibrate at high speeds. In the rear axle there should be no play whatever in the fits at the ends of the axle shafts, and there should be no play or backlash in the inside differential-gears. The differential should actually turn over tight, when new. The driving bevels must have a running backlash, but this should be the minimum.

Summing it all up, we can assert with confidence that a remarkable improvement in the quietness of the car and its transmission can be made by careful attention to balance and weight on all fast rotating parts and by a general tightening, up to the practical limit, of all working parts from end to end of the chassis.

M. C. HORINE[5]:—I think we do not want to go on record as dismissing gear grinding as being quite as useless a thing as appears to be the opinion of some. Various methods of grinding gears exist but, if the generator grinder is used, it is certainly true that a heat-treated or hardened gear can be generated more accurately on the grinding machine than it can be cut originally. Another very important advantage of the ground gear mentioned by Mr. White is the smoothing of the teeth. The minor irregularities which are always left in the machining operation can be smoothed by grinding as they can be in no other practical manufacturing method. A great deal in the way of the reduction of gear-tooth distortion has also been done by the upsetting process of forging gear-blanks.

Considerable can be done toward the reduction of transmission noise by returning to the old ideas for general transmission-design. I believe that the conventional unit-powerplant transmission is essentially a noisier design than the old-type amidship-transmission, for several reasons. First, the unit-powerplant transmission having a bell housing is, as the name suggests, a very good bell. The countershaft, being located below the spline shaft, is immersed in oil, and a bell will not ring satisfactorily when immersed in a liquid; but the spline shaft, being entirely above the oil, allows its gears to act as bells. In the side-by-side arrangement, both sets of gears are partly immersed in oil and, therefore, are less likely to act as bells. The amidship transmission, being separated from the engine, is less likely to suffer from amplification of engine vibration, and it is also possible to mount the transmission as a whole, independently from the frame, even going so far, if desirable, as insulating it from the chassis to some extent by the use of rubber or other flexible means of support; and the alignment of the shafts can be controlled much more favorably if the transmission is mounted independently than if it is bolted rigidly to the crankcase and more or less rigidly coupled to the crankshaft, which two are not necessarily always concentric.

C. W. SPICER[6]:—In regard to the amidship transmission, moving the transmission back has the effect of shortening the propeller-shaft. That of itself will reduce the length and very often will reduce the required diameter and consequently the weight; and, as the tubing which is commonly used has unavoidable inaccuracies due to manufacture, the likelihood of excessive out-of-balance due to inaccuracies of the tube increases rapidly with the size of the tube. Hence, if the tube can be kept down in diameter, the condition in reference to vibrations can be improved very much.

EDWARD S. MARKS[7]:—In connection with Mr. Horine's argument for amidship transmission, and on account of having just the opposite experience from his, I will relate it. Until 1922, we had the amidship transmission and, so far as we knew at that time, we were using every care to make the gears according to the best practice, to make the mountings according to the best practice and to use accurate workmanship in manufacture. But we were never able to obtain anywhere near so quiet a transmission, with regard to gear noise, as we did when the first unit-powerplant transmission was built. The succeeding transmissions have duplicated the first, and our production transmission has been very much more quiet than we ever were able to obtain with the amidship transmission.

CHAIRMAN K. L. HERRMANN[8]:—That is exactly our experience; our 1925 series is much more quiet than our amidship transmissions ever were.

MR. MARKS:—Our first experience with the unit-powerplant-transmission construction also brought to us a problem in gear rattle which has been mentioned here. We found it necessary at that time to specify very close limits between the sliding gear and its slide-shaft and between the engine clutch-gear and the sliding gear that goes into it. To obtain a good job, we found it absolutely necessary to require standards of our manufacturing department which seemed very hard to maintain. Subsequently, all this difficulty was found to be due to periodic engine-vibrations; these we eliminated by introducing a flexible member into the clutch-driven disc. The foregoing confirms both Mr. White's and Mr. Buckingham's ideas of external sources of noise, enabling us to use good manufacturing practice and, at the same time, to prevent rattling transmissions.

FUNDAMENTALS OF BRAKE DESIGN

BY OTTO M. BURKHARDT[9]

ABSTRACT

THE object of the paper is to contribute some new and fundamental concepts to the mechanics of machinery. The scope is limited to the subject of brakes, which was found to have been somewhat neglected in the past. To make the paper self-contained, some well-established laws on sliding friction are given as groundwork. Attention is called to facts that have been ignored in some textbooks because of apparent insignificance, although they are of vital importance in the special subject of brake design.

An analysis of the force relations for simple block-brakes is given first, with the intention to make clear that the equations so far available for designers are not sufficiently accurate for brakes such as are used on modern motor-vehicles and railroad coaches.

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[6] M.S.A.E.—Vice-president and chief engineer, Spicer Mfg. Corporation, South Plainfield, N. J.

[7] M.S.A.E.—Chief engineer, H. H. Franklin Mfg. Co., Syracuse, N. Y.

[8] M.S.A.E.—Assistant manager, methods and standards division, Studebaker Corporation of America, Detroit.

[9] M.S.A.E.—Research manager, Society of Automotive Engineers, Inc., New York City.

Attention is called to the fact that the wear on brake liners is not necessarily an indication of high pressures, but more accurately is a function of the geometric relation between the shoe and the drum. It is acknowledged that for flexible liners the center of pressure is nearly in that horizontal axis where the wear is maximum, but it is proved that after the liner is glazed high local-pressures are very likely to occur momentarily where the wear is very slight. Attention is called also to some difficulties encountered in adjusting brakes as well as in manufacturing them.

Formulas are given for the study of the self-energizing characteristics of brakes. These should be very helpful in connection with four-wheel-brake designs, because it was recognized very early that with doubling the number of brakeshoes very high foot-pressures were required to obtain satisfactory retardation.

An empirical rule frequently used for determining roughly the arc of contact is discussed but is found insufficient for modern, more exacting requirements. Instead, a new graphical method is given. This new method is based on an analysis of the pressures and is formulated so that high pressures with their accompanying evils are avoided. Adherence to the method given leads to the more modern brake-design with multiple shoes. In the analytical work, limiting conditions are extensively discussed. These mathematical discussions serve as groundwork for the recommended graphical method. Some advantages of brakes with three shoes are given. One of these is the large arc of contact that can be obtained.

An effort is made to prove that squeaking, chattering and grabbing are not necessarily a result of a variation in the coefficient of friction. Diagrams are given to show that pressures are just as likely as the coefficient of friction to cause this trouble. In modern designs, a high friction-coefficient is desired, and means are provided to keep it constant; therefore, even pressure-distribution is stated to be important.

In conclusion, the railroad type of brake is discussed. It is pointed out that pressures cannot accumulate in it as in other types; therefore, this type is recommended for applications where chattering is likely to be pronounced because of the existence of backlash and where great mechanical advantage is of lesser importance. [Printed in the July, 1925, issue of THE JOURNAL.]

THE DISCUSSION

C. L. SHEPPY[10]:—Regarding Mr. Burkhardt's statement in reference to aluminum brake-shoes and brake-drums, it may be that, so far as rigidity and heat dissipation are concerned, he is correct; but we must keep in mind that brakes, to be effective, must be capable of being applied and held on for practically an indefinite period, even though they generate considerable heat. The coefficient of expansion of aluminum is much higher than that of steel and, in actual practice, it has been found that the aluminum brake-shoe and the steel brake-drum compensate for the difference in the temperatures of the two. In other words, with an ordinary plain steel brake-drum or a drum with ribs on it to dissipate the heat rapidly, the drum does not expand nearly so rapidly as an aluminum drum. Aluminum brake-shoes expand more rapidly than shoes made of steel or cast iron, and they compensate for the expansion of the steel drum. We have found in actual practice that, with the proper proportions between a steel-ribbed drum and aluminum brake-shoes, the brakes can practically be held on indefinitely if enough radiation surface is provided by the drum to dissipate the heat.

The subject of brake-squeaks, groans and chatters is very interesting. If one's thumb is moist when rubbed over the arm of a chair, and one continues to press the thumb harder and harder, a change takes place in the amount of moisture on the thumb and the coefficient of adhesion changes. Consequently one can create a squeak in this manner. I think that a drum and its shoes should be rigid and that the combination should possess no flexibility if it is possible to design them so, but I still think that the heat created by friction, the quality of the brake-lining and atmospheric conditions have very much to do with brake-squeaks.

I grant that brake-grabbing possibly is traceable to poor design, but I believe that brake-squeaks always will exist so long as brake-linings are used. The fact is that, when a drop of oil is put on them, the squeak disappears until such time as the oil is rubbed off or burned off, or atmospheric conditions change so that the right condition is developed to produce a squeak.

CHAIRMAN W. R. STRICKLAND[11]:—In reference to Mr. Sheppy's illustration regarding one's moistened thumb, it makes a difference as to the noise whether one pushes or pulls. When pushed, a building up of pressure that causes chatter occurs; but pulling the thumb creates a normal pressure without noise.

A. Y. DODGE[12]:—One value of Mr. Burkhardt's paper is that he has touched upon a method for deriving formulas by which we can calculate what a brake-shoe will do. We have had formulas on band brakes, but I have been unable to find formulas on shoe brakes, and have worked out my own. I have used the force diagrams that Mr. Burkhardt has pointed out for more than a year. I wish he would carry the paper further and consider the concentric versus an eccentric brake. Very few internal-shoe brakes are made that are concentric when applied and eccentric when not applied. That has a great influence on the diagram of forces.

Mr. Burkhardt has pointed out what forces might be encountered momentarily with highly rigid drums. I cannot agree with him that at the middle of the lining, where the greatest wear comes, we do not get the greatest pressures. It is true that we may get the greatest pressures at some place other than at the center of the shoe momentarily; but, over a period of time, the greatest average pressure must come where the wear is greatest. With a round drum, turning true, and a concentric brake well lapped-in, the maximum pressures would be where the maximum wear occurs. Since it is impracticable to have perfectly round drums, we must have eccentric drums and with them we must get momentary high pressures at these high-leverage points. Mr. Burkhardt could carry this a little further and calculate the amount of deflection. While the modulus of elasticity of steel is high, we know the shape of a brake-drum is such that its section modulus is low for a small amount of deflection. It is very easy to deflect a brake-drum a few thousandths of an inch.

H. D. HUKILL[13]:—In outlining the difficulties of a self-energizing brake, Mr. Burkhardt presented rather a good brief for the power-operated brake. Those difficulties are multiplied in the motorbus brake, where braking service is most severe and where the wear on linings is correspondingly more rapid. The brake not kept in correct adjustment is the one most prone to squeal or chatter and, in motorbus service, it has been found that rigid brake-anchorages are an absolute necessity to prevent brake-squealing. In any self-energizing

[10] M.S.A.E.—Chief engineer, Pierce-Arrow Motor Car Co., Buffalo.
[11] M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.
[12] M.S.A.E.—Chief engineer, Perrot Brake Corporation, South Bend, Ind.
[13] M.S.A.E.—In charge of automotive division, Westinghouse Air Brake Co., Wilmerding, Pa.

or wrap-up type of brake, the equations include the coefficient of lining friction raised to an exponential power, and any variation in lining friction is reflected in a considerably greater variation in the final braking-effect. I do not know that a fabric brake-lining has been produced in which the coefficient of lining friction can be held constant over a continuous run of 5 min. under normal service-conditions. Numerous mechanically operated metal-to-metal brakes have been tried and discarded in the past, but it has been found possible to build a most satisfactory power-operated metal-to-metal brake of the two-rigid-shoe internal-expanding type. Air under pressure is used as an actuating medium. Climatic and atmospheric conditions have no effect on the operation of this metal brake, and it can be built rigidly enough to be free from squeals and chatters at all times. The metal brake retains its effectiveness on heavy grades because, with no layer of heat-insulating fabric to interfere, heat can be dissipated much more rapidly. The metal brake is also satisfactory for operation at temperatures much higher than those permissible with fabric linings. Under similar conditions, the average service life of a metal brake-lining is from 8 to 10 times that of a fabric brake-lining.

F. C. STANLEY[14]:—Naturally, I am interested in the demands made on brake-lining by various designers. In making a comparison I have based the power of absorption on making stops at 20 m.p.h. and find that the energy absorbed varies all the way from 124 to more than 2000 ft-lb. in different installations. For example, with a 5-ton truck, 120 sq. in. of brake-lining may be used and the same area of brake lining may be used on a passenger car that weighs about 2000 lb. or on a truck weighing 5000 lb. This difference in the requirement of the brake-lining makes a great difference in the matter of service. In that connection, the best engineers have introduced 0.85 per cent of carbon into the clutch plate because they found that scoring occurred in the clutch plate, but they still are using from 0.10 to 0.20 per cent of carbon in the brake-drums. We find sometimes that brake-drums are very severely scored. The scoring makes it impossible to have perfect contact of lining and, where imperfect contact exists, we have high unit-pressures and part of the drum is free to vibrate; hence, it squeaks. We are unable to stop squeaks where we cannot get a reasonable contact of lining and drum, and that occurs due to wear.

Regarding internal brakes, as determined from actual service, where the internal brakes are not concentric but are eccentric, being mounted usually on pins at each side of the anchor, I found a case of 0.025-in. wear of the drum, meaning 0.050-in. reduction of its diameter. Hence, as these shoes spread, they are in contact with the drum only at the points, which tends to produce a squeak and also causes inefficiency. The wear on the liner, if even, would not produce the same results; but, when the wear is on the drum, only the points of the shoes, the toes, as Mr. Burkhardt calls them, are brought into contact with the drum.

CHARLES FROESCH[15]:—Mr. Burkhardt's paper is interesting from the designer's point of view. His graphic representation of the brake-lining pressures of an internal-shoe type of brake shows, among other things, that the brake-shoe anchor-pin should be as near to the drum as possible. To obtain the greatest leverage, this location, however, must be compromised because the minimum cannot be less than the radius of the anchor pin plus the shoe bearing-thickness. Furthermore, if we followed this graphic determination, it will require a certain amount of cam motion to take up the brake-lining clearance. The nearer the anchor pin is to the drum, the greater this motion is for a given lining-clearance. Of course, this can be kept somewhat constant by providing radial adjustment at this point to take care of lining wear.

Mr. Burkhardt mentions motorbus service as being the hardest brake-service. This, undoubtedly, is true. If we take the case of a 25-passenger inter-city coach, weighing about 14,000 lb. and traveling at a speed of 45 m.p.h., a kinetic energy of approximately 1,000,000 ft-lb. is stored in the vehicle. All we have available in the way of power with which to apply the brakes is the push and the pull of the driver, amounting to about 200 ft-lb., or a ratio of 5000 to 1. The maximum mechanical advantage that can be used to multiply this physical effort cannot be made to exceed 40 to 1 unless adjustments become too close so that we have at the wheel and the ground contact a possible maximum effort of 8000 lb. applicable to stop the vehicle. The use of self-wrapping brake-shoes may multiply this effort, but it is not adequate and introduces complications. Power brakes are essential to supply the necessary effort. Their application is, of course, limited, as another important aspect is the matter of acceptable rates of deceleration to conform with the passengers' comfort, in the case of a motorbus, or to prevent injury to the lading in case of a truck. This is shown by the application of the Scotland Yard formula for passenger vehicles in London, which calls for a stopping distance in feet equal to the square of the speed in miles per hour, divided by 10. This corresponds to a retardation of about 11 ft. per sec. per sec. Incidentally, the Bureau of Standards tests show the same average rate of retardation on dry pavement for two-wheel-brake cars.

To dissipate the heat generated when braking a motorbus, large drum-surfaces are necessary due to the lack of heat transference of present-day woven-linings. The use of metal shoes of course permits the dissipation of heat both ways, but their coefficient of friction is much lower. To meet all these requirements, either the brake-lining pressure must be high or the size of the brake-

TABLE 1—BRAKE-PERFORMANCE DATA

Assumptions	Model-*AB* Truck	City Motorcoach	Sedan Motorcoach
Chassis and Body Weight, lb.	8,200	9,316	10,200
Pay Load, lb.	5,000	6,000[a]	3,300[a]
Total Weight, (W), lb.	13,200	15,316	13,500
Weight Distribution, (w_d), per cent			
Front	35	35	40
Rear	65	65	60
Rear-Axle Gear-Ratio	9.25	6.70	5.88
Rear-Wheel Diameter, in.	36	32	36
Maximum Speed, (V), on High Gear, m.p.h.	20	30	45
Speed, (v), in ft. per sec.	29.4	44.0	66.0
Coefficient of Friction of the Tire, (f), at the Ground	0.6	0.7	0.7
Braking Efforts Required and Results Obtainable			
Kinetic Energy, ($E = Wv^2/2g$), at Maximum Speed, ft-lb.	177,100	460,000	915,000
Maximum Braking Effort, ($e = Ww_df$), Applicable, lb.	5,150	6,960	5,670
Stopping Distance, ($s = E/e$), from Maximum Speed, ft.	34.40	66.00	161.00
Scotland Yard Formula, ($V^2/10$), Stopping Distance, ft.	40.00	90.00	200.00
Deceleration, ($g = v^2/2s$), in ft. per sec. per sec.	12.60	14.70	13.50
Stopping Time, ($t = v/g$), in sec.	2.34	3.00	4.90

[a]Average weight of passenger, 150 lb.; city coach, 25 seated and 15 standing; sedan, 22 seated.

[14] M.S.A.E.—Chief engineer, Raybestos Co., Bridgeport, Conn.
[15] M.S.A.E.—Engineer, International Motor Co., New York City.

drum and the area must be large, thus increasing the weight.

A study of various braking tests made with trucks and motorcoaches reveals that the maximum braking-force that can be applied by human power is from 5500 to 6000 lb. The difference between this figure and the figure mentioned previously is probably due to friction. This is mentioned here because it indicates the necessity of some sort of servo-mechanism if four-wheel brakes are to be used, and for the heavier vehicles that travel at high speed, as shown in Table 1.

How can Mr. Burkhardt reconcile theory and practice as to pressure and wear?

OTTO M. BURKHARDT:—The pressures stated in Figs. 10, 13, 14 and 17 are instantaneous pressures only. High pressures lasting for infinitely short time-intervals only are characteristic for squeaking and chattering brakes. Wear, however, is a function of time and therefore will occur where contact is continuous; namely, in the middle of the shoes. The geometric relation of the brake-shoe to the drum necessitates uneven wear; that is the theory and, on this, we all agree. The fact that brake-shoes are self-wrapping permits uneven pressure distribution. This has been found to be the case in practice. The reasons for it are given in my paper.

GEORGE B. ALLEN[16]:—I agree with Mr. Burkhardt that the wear of brake-lining is not a direct function of pressure distribution, and that a number of reasons why wear is excessive at certain points of the brake-lining under actual road-conditions exist. His analysis of servo-brake mechanisms should be of practical interest at present, and the ideas set forth in his paper should result in a more practical research relating to the various braking systems.

H. D. CHURCH[17]:—Apparently Mr. Burkhardt has reverted to the elementary principles of brake design. When working on highly advanced brake designs, a tendency always exists toward losing sight of fundamentals. This is illustrated by the sudden and somewhat premature adoption of four-wheel brakes.

W. R. GRISWOLD[18]:—I concur with the statement that reasoning based on the premise that greatest wear takes place at points of highest pressure is likely to be very misleading, for wear is a function of pressure, and velocity of rubbing between the surfaces, and time. Obviously, the element of time may have considerably more influence on wear than either pressure or velocity.

In regard to the inaccuracies of new brakes operating with hard liners that permit, according to the figures quoted, contact at the ends of each liner, it should be noted that this is true provided no burning-in process is practiced to obtain good initial fit of the brake-liners to the drum, and in a measure it emphasizes the importance of such practice for getting satisfactory brake operation from the very start.

It should be pointed out that an important discrepancy seems to exist which should be explained in connection with the analysis of brake-squeaking and chattering to make Mr. Burkhardt's analysis clear. After analyzing the pressure relations for an elementary brake-shoe, which is mathematically stated by Equation (7), Mr. Burkhardt draws the curves shown in Figs. 10, 13 and 14, which are denominated variously as "pressure-distribution" curves; as, for instance, in Fig. 13, the caption reads: "Approximate Pressure-Distribution in Three-Shoe Brake-Designs". Unfortunately, it is not so easy to say exactly what these curves do represent in language that does not sound like a physician's diagnosis, but a serious student in mechanics will first want to know by what license a locus of pressures for an infinite number of brake-shoes, varying only as to the infinitesimal differences of contact position on the drums, can be called a pressure-distribution curve, presumably for a solid shoe. This license is particularly puzzling when the following points are considered.

In Fig. 4 and in the text relating to the discussion of pressures it is shown that, for elastic contact, the pressure at A_2 will be less than that at E_2. Referring to Fig. 6, it is evident that this same general relation holds true for the internal type of brake; to wit, that the greatest normal displacement between the liner and the drum takes place approximately at the middle of the contact length for a given angular displacement of the brake-shoe about its pivot. If we consider that the liner is perfectly elastic as indicated by the springs in Fig. 4, it is apparent that the greatest normal pressure between the brake-liner and the brake-drum occurs at the point of maximum normal displacement, and from this it would follow that the pressures on the brake-liner would be less at the ends than at the middle of contact.

Again, if we consider that the liner is perfectly rigid, it is evident that the pressures at the ends of the liner will be zero and the contact between the liner and the drum will be a line through the point of maximum normal-displacement. This leads to the interesting conclusion that, if the liner is perfectly elastic, the pressure at the ends of the liner cannot exceed the pressures at the middle of the liner; and, if the liner is perfectly rigid, then the pressures at the ends of the liners will be zero. This raises the question of how such pressure distributions, as shown in Figs. 10, 13 and 14, can come about; since in either case of flexible or rigid liners the pressures are higher at the middle of the liner. No doubt Mr. Burkhardt has considered another element that he has not expressly stated in the paper, such as, for instance, the distortion of the brake-shoes under load.

The foregoing discussion or the fact that Mr. Burkhardt decided to hold to simple language at the risk of being misunderstood has nothing whatever to do with the fidelity of his conclusion, which, to quote him, is:

> To sum up this analysis, we can now state with fair degree of accuracy that, if any contact takes place over the arc of the brake-drum which is subtended by the angle β, something very undesirable will happen.

But the quotation is made merely to bring out an explanation of the "if" in that conclusion. Under what conditions or circumstances will contact take place in this critical region of the lining?

MR. BURKHARDT:—Mr. Griswold objects to the caption "Approximate Pressure Distribution" and to others. From the text, however, Mr. Griswold has read the exact meaning of the illustrations. The word approximate was used to make possible the stating in three words what was stated in many sentences in the text. Figs. 10, 13, 14 and 17 are graphic representations for mathematical equations. For instance, it is stated in the text on p. 70 that Fig. 10 represents a general application of equations (3) and (10) which apply to elementary brake-shoes. It is nowhere contended that the pressures depicted in Figs. 10, 13, 14 and 17, are acting simultaneously. If they were, probably no squeak or chatter would occur.

Moreover, Mr. Griswold assumes that the pressures on the ends of rigid liners are zero. This mistaken assumption is the real reason that he cannot agree with all the conclusions given in the paper. It is a well-known fact

[16] M.S.A.E.—Research engineer, Dodge Bros., Detroit.
[17] M.S.A.E.—Director of engineering, White Motor Co., Cleveland.
[18] M.S.A.E.—Engineer in charge of analysis of design. Packard Motor Car Co., Detroit.

that brake-shoes are arcs of circles that have loads applied at both ends. Hence, we must at once agree that deflection will take place under the influence of these loads. This deflection causes a change in the curvature from a circular to an elliptic form. With elliptical brake-shoes, contact will take place at the ends and pressures of the order indicated in Figs. 10, 13, 14 and 17 will arise. Their duration, of course, is instantaneous. This intermittent contact caused by deformation is exactly the cause for squeaks and chatters.

D. FERGUSSON[19]:—I am particularly interested in Mr. Burkhardt's conclusion in regard to the superiority of the three-shoe brake, showing as he does the limitations to the length of contact in designing the two-shoe brake correctly, utilizing less than two-thirds of the circumference of the brake-drum, leaving absolutely unutilized one-third of this surface and demonstrating the logical need for an additional shoe. Our company has adopted the Bendix-Perrot three-shoe type of brake, and we are now fitting all our cars with it. The diagrammatic arrangement is shown in Fig. 1. The primary shoe is a floating shoe anchored only to the secondary shoe at *a*. The secondary shoe is anchored to the backing plate at *b*. Cross-hatched portions indicate the backing plate and the dust shield. The auxiliary shoe is anchored to the backing plate at *c*. The cam actuates the primary shoe and, through the primary shoe, pressure is exerted on the secondary shoe. Force due to friction aids in pressing the secondary shoe against the drum, which corresponds to servo action. In reverse, the auxiliary shoe operates directly from the cam.

We have adopted a high-carbon pressed-steel brake-drum with a flange turned up about $\frac{5}{8}$ in. high at the open end of the drum. This makes a very rigid brake-drum. Although it will not radiate heat so rapidly as the type of brake-drum with a series of ridges on the outside, it appears to be perfectly satisfactory for four-wheel brakes when no outer brake-bands are used; in fact, we discovered recently that these brake-drums apparently cool off too rapidly as compared with the internal aluminum brake-shoes. When coming down an exceedingly steep hill about 2 miles long, using four-wheel brakes only to check the speed, we found that the brake-drums and brake-shoes expanded uniformally all the way down the hill; but, when running for $\frac{1}{2}$ mile on the level and then climbing the other side of the valley, we found that the brake-drums cooled off more rapidly than did the brake-shoes. The result was that the brakes dragged and, finally, almost stalled the engine while climbing the opposite steep hill. This clearly showed that the internal brakes were too thoroughly enclosed, no circulation of air being present; we therefore made a small louvre in the cover over the inspection hole in the web of the brake-drum, thus impelling air to enter into the interior of the brake-drum and so assist in cooling off the aluminum brake-shoes. This entirely overcame the trouble.

We find that it will be necessary to put double the number of rivets in the brake-lining attached to the secondary brake-shoe. Originally, the rivets in this shoe were spaced almost 4 in. apart but, we are now spacing them 2 in. apart, as we had one or two instances in which the brake-linings would creep on the brake-shoes. It seems that room for improvement in regard to attaching brake-linings to the brake-shoes exists. The counter boring of the lining to bury the rivet heads well below the surface of the lining leaves very little material underneath the head, in the case of a lining 3/16 in. thick. This thickness of lining should be satisfactory where four-wheel brakes are used, and when a liberal area of brake-lining is employed.

Considerable progress has been made in the development of satisfactory four-wheel brakes since 1924. The experience of many users of four-wheel brakes of different makes has shown the weak points of some of these systems and few systems did not have weak points. Some of these weak points were so bad that the brakes have been entirely redesigned and some are so radically changed that they must go through a long period of testing before they can be regarded as absolutely satisfactory. Our company has always felt more favorable toward mechanically operated four-wheel brakes, but the directly applied mechanically operated four-wheel brakes were not satisfactory on heavy, powerful cars, as the average driver had not sufficient strength to stop the car in a reasonable distance. It must be remembered that it requires double the effort on the part of the driver to apply the brakes to the full extent on four-wheel-brake cars, than is required on rear-wheel-brake cars, if the leverage and the diameter of the brake-drums are the same. All drivers of large cars know that they have all they can do to apply the brakes to the full extent with rear-wheel brakes only, and it is impracticable to rely solely upon the driver's efforts to actuate mechanically operated four-wheel brakes on the largest cars.

A braking system that gives satisfaction on a small light car may be a failure on a heavy one. Some heavy cars are equipped with direct mechanically applied four-wheel brakes, but they sacrifice much efficiency; the operator should be able to stop the car in half the distance required with fully effective rear-wheel brakes, but some of these cars do not come within 40 per cent of this; that is, their four-wheel brakes are but little better than really good rear-wheel brakes. On some other heavy cars the leverage is increased to help out the driver. This is a questionable practice as it gives too little clearance between the brake-shoes and the drum, and is liable to give trouble due to having the brakes bind when they are supposed to be in the off-position. Also, with the great multiplication of leverage, the foot pedal reaches the floor-board too quickly and therefore requires adjustment at short intervals. The builders of these heavy cars are adopting devices that longer European experience has proved to be unsatisfactory and which were abandoned in Europe 3 or 4 years ago.

Air brakes and hydraulic brakes are subject to derangements due to leakage developing that may at any moment render the brakes useless. The cylinders and plungers are necessarily of such small displacement that the slightest leakage will be very detrimental and may cause an absolute failure at a critical moment and without warning. On the other hand, the failure of mechanically operated brakes is almost always very gradual and the driver has fairly effective brakes for a long time before complete failure occurs, which gives him ample time to make adjustments.

In Europe, mechanically operated four-wheel brakes have been in use for many years, the Perrot system being particularly successful. This system is used on the majority of cars built in England, France and Italy, and this make of brakes is without question a great success in all small cars. In the larger and more powerful cars a supplementary power device had to be developed to enable the driver to stop these heavy rapidly moving vehicles in a reasonable distance. This resulted in a very intricate and trouble-inviting mechanism that util-

[19] M.S.A.E.—Chief engineer, James Cunningham, Son & Co., Rochester, N. Y.

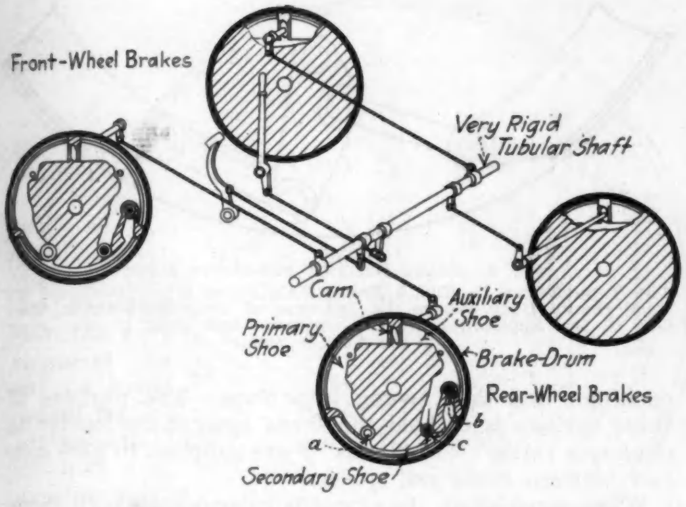

FIG. 1—BENDIX-PERROT FOUR-WHEEL-BRAKE ARRANGEMENT
The Primary Shoe Is a Floating Shoe Anchored Only to the Secondary Shoe at *a*. The Secondary Shoe Is Anchored to the Backing Plate at *b*. Cross-Hatched Portions Indicate the Backing Plate and Dust Shield. The Auxiliary Shoe Is Anchored to the Backing Plate at *c*. The Cam Actuates the Primary Shoe and, through the Primary Shoe, Pressure Is Exerted on the Secondary Shoe. Force Due to Friction Aids in Pressing the Secondary Shoe against the Drum, Constituting Servo Action. In Reverse, the Auxiliary Shoe Operates Directly from the Cam

ized the power of the engine or some revolving part of the mechanism to apply the brakes, the driver having to exert but a small fraction of the power needed to force the brake-shoes against the drums. This mechanism acted in the same manner as does the steam-operated steering-device used on large vessels where the man at the wheel exerts practically no effort to move the rudder, which requires the application of many horsepower to change its direction. The Hispano Suiza and the Renault companies developed wonderfully effective but very complicated devices for applying automobile brakes along these lines. The results obtained led to the development of a very simple self-wrapping brake-shoe that multiplies the power of the driver about three times and the brake-shoes are automatically forced into engagement by the revolving brake-drum whenever the driver presses on the brake-lever. This is one of the Perrot inventions and it has lately been further developed so that it leaves but little to be desired. We have confidence in recommending this type of four-wheel brake for use on our cars, after having tried this system out thoroughly.

All Perrot four-wheel brakes are of the internal-expanding type. They are thoroughly enclosed and very effectually protected from mud, water or dust, the brake-drums are flanged to prevent distortion and they are very effectively air-cooled, no external brake-bands to hinder the cooling of the brake-drums being used. The brakes are hooked up to the foot and to the hand levers so that the foot-brake lever actuates all four sets of brake-shoes and the hand brake also actuates all four sets. These are coupled-up so that practically no stretch or deflection of the parts actuating the brake-shoes is found. Therefore, every fraction of an inch of movement of the pedal or of the hand-brake lever results in a corresponding movement of the brake-shoes. Should one of the front-wheel brake-rods or levers become fractured, three wheel-brakes will be left to stop the car. If both front-wheel brake-rods fractured, two rear-wheel brakes would still be left to stop the car. If one of the rear-wheel brake-rods, together with two of the front-wheel brake-rods fractured, one wheel-brake that would be effective would still remain. This system appears to offer the greatest safety. With these brakes, it is not possible to lock the front wheels when making a turn.

In Europe, mechanically operated four-wheel brakes are used to the exclusion of all other types. At the last Automobile Show, 99 per cent of the cars were equipped with these brakes, about 75 per cent of these cars have the Perrot four-wheel brakes and the majority of them have adopted the self-wrapping type that automatically increases the effort of the driver from two to three times.

E. B. FLANIGAN[20]:—I have gone over Mr. Burkhardt's paper very carefully and I believe that he has made plain the causes for many brake troubles. Practice seems to bear out his theory. In the case of the conventional shoe-brake, the same pressure P is applied by the cam to both shoes. If we let Q_2 equal the braking effort of the one shoe and Q_1 that of the other shoe when the drum is traveling clockwise, then, using Equations (4) and (6) as stated by Mr. Burkhardt, we get

$$P = Q_1\,(b - fc)/fra$$
$$= Q_2\,(b + fc)/fra$$

or

$$Q_1/Q_2 = (b + fc)/(b - fc) \qquad (16)$$

This clearly shows that one shoe is less effective than the other shoe and more braking in the forward direction would be obtained by omitting the less effective shoe. However, this would increase the unit pressure of the remaining shoe. It is also evident that incorrect location of the hinge-pin, inaccuracies of machining or deformed shoes will materially affect the braking action.

With the advent of the four-wheel brake and the increase in speed of heavy-duty trucks, it has been found advisable to decrease the applied pressure and still obtain powerful braking. This has been attempted in several ways. The conventional shoe-brake has been modified to take advantage of self-energizing action. As apparent in Mr. Burkhardt's diagram, this greatly increases the unit pressure as the contact is then near the cam end of the shoe. This method has not been entirely satisfactory for this reason. Several brakes similar to the servo type have been tried. With this design the hinge-pin connecting the two shoes has been some distance in from the circumference of the drum. This produces a moment as shown in Mr. Burkhardt's Fig. 1 and tends to bend the shoes away from the drum at this point. I understand that this difficulty actually has been experienced; also, with some designs, the reverse braking-action was not sufficiently effective.

The next step forward was the use of three shoes. As Mr. Burkhardt points out, one shoe is always not doing full duty due to the unwrapping action.

Internal full-wrap-up brakes have been used to some extent in the past but, as a rule, full contact was not obtained. If the brakes were operated by a one-way cam, difficulty in obtaining sufficient braking-effort in reverse was encountered. For this reason, a floating toggle has sometimes been used. A stop to take the braking action was then required and both shoes, or both ends of the band, would not be in contact with the stop unless continually adjusted. This produced a grabbing brake and one that would wear excessively at the ends.

I have devised a brake that takes advantage of the powerful self-energizing effect of the full-wrap-up brake without incurring any of its disadvantages. In Fig. 2, this brake is shown for medium-capacity trucks and in Fig. 3 it is shown when designed for very heavy duty where the pressure between the application by the operator and that of the lever on the axle is increased slightly. The cam *d*, Fig. 2, is a differential cam, as is clearly

[20] M.S.A.E.—Field engineer, Sheldon Axle & Spring Co., Wilkes-Barre, Pa.

shown in Fig. 4, having more throw downward than upward. If a single-throw cam is used, the contact point of the cam and lower shoe is at R_2, while for the differential cam it is at R_1; hence, in reverse, the single-throw cam gives a large moment tending to close up the cam against the operator. When traveling forward, if the differential cam is used, the reaction from the upper shoe comes very nearly over the cam axis, so that the forward braking is very little affected. Slightly better braking is obtained in the forward direction than in reverse. Also, the upward throw as the cam turns is equivalent to adjusting the stop for the upper shoe automatically. This takes up some of the clearance between shoe and drum and obviates the necessity of frequent adjustments. The lower shoe *e*, Fig. 2, is hinged to a movable link *f* and the upper shoe *g* is hinged to a movable link *h*. The two links *f* and *h* are hinged to the link *i* that is suspended from the pin *j* which is integral with the brake-spider. At the opposite end, both shoes are at all times in contact with the differential cam *d*.

When the brake is applied, the cam *d* forces the lower shoe *e* about the link *f* until the shoe attains full contact

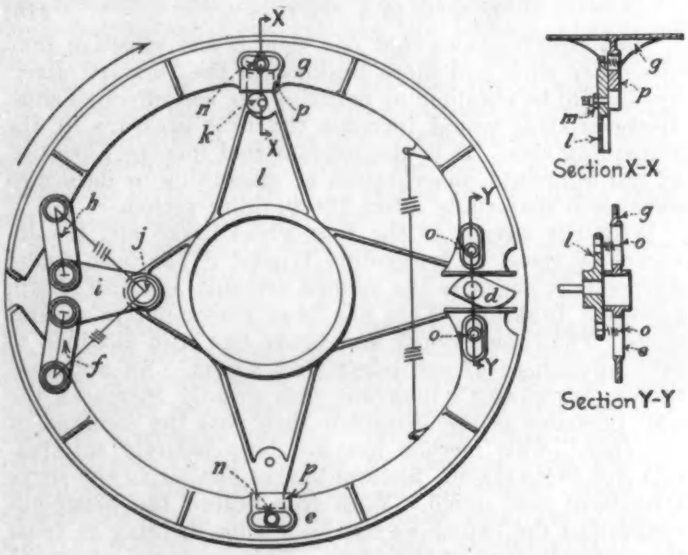

FIG. 2—SPECIALLY DESIGNED TYPE OF BRAKE
Advantage Is Taken of the Powerful Self-Energizing Effects of the Full-Wrap-Up Brake without Incurring Its Disadvantages

with the drum. The shoe *e* will then exert a pressure along the link *f* and this link and the shoe *e* will travel around with the drum, straightening out the toggle *h-i*. This will produce a pressure along *h* which will have both a normal and a tangential component applying the shoe *g* to the drum. The drum will now carry both shoes along until the shoe *g* comes into contact with the drum at the cam end. Both shoes must now be in contact for their entire length. The link *f* wedges the shoe *e* into the drum and the link *h* not only applies a tangential pressure to the shoe but also applies an appreciable normal pressure. This increases the friction at this point and builds up additional braking-resistance.

The shoes *e* and *g* are identical and may be die-castings. The links *f* and *h* are identical. The eccentric shoe-support *k* is attached to a shaft having a bearing in spider *l* and clamped by the nut *m*. A full-width shoe is shown and this is operated by the differential cam *d*. This cam receives the brake reaction and has a larger-diameter bearing in the brake-spider than does the shaft operating it. The springs *n* and *o* are held in place by small rods resting in grooves in the brake-shoes. The rods are short enough to be pulled through the cored

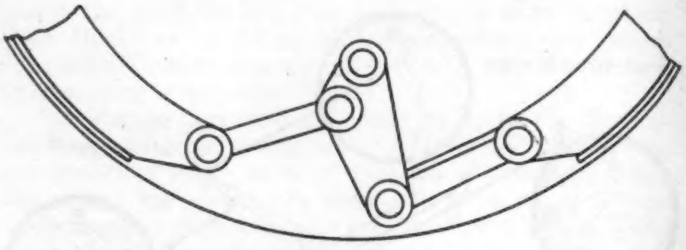

FIG. 3—BRAKE DESIGNED FOR HEAVY DUTY
The Type Shown in Fig. 2 Takes This Form When Designed for Very Heavy Duty Where the Increase of Pressure between That Due to the Application by the Operator and That of the Lever on the Axle Is Small

openings, and then swung into place. The purpose of these springs is to hold the shoes against the spider to eliminate rattle. The "lands" *p* are supplied to give contact between shoes and spider.

When assembling, the cam *d* is turned until both shoes are in contact with the drum. The nut *m* is loosened and the eccentric support is turned until it is in contact with the upper shoe. The support is then backed slightly and the nut *m* is tightened. No further adjustment is necessary other than rotating the cam. At rare intervals it is possible to readjust the support *k* until the minimum clearance is obtained between the upper shoe *g* and the drum. To remove the brake for relining, it is only necessary to unsnap the springs *n* and *o* and to remove the cotter-pin in the hinge-pin *j*. The entire assembly can then be lifted off. The design lends itself to full width, parallel shoe or front-wheel brakes. It can be manufactured very cheaply and has the minimum number of parts. Adjustment is very seldom needed, but it can be made from the outside whether the brake is open or is supplied with a dust shield.

The following advantages are obtained:

(1) A full-wrap-up brake is obtained in which both shoes are working for their entire length. Powerful braking-action is obtained without high unit-pressure being localized, with the attendant faults, as brought out by Mr. Burkhardt

(2) The shoes will tend to shape themselves to the drum, instead of buckling as is the tendency if the shoes are directly pinned to each other

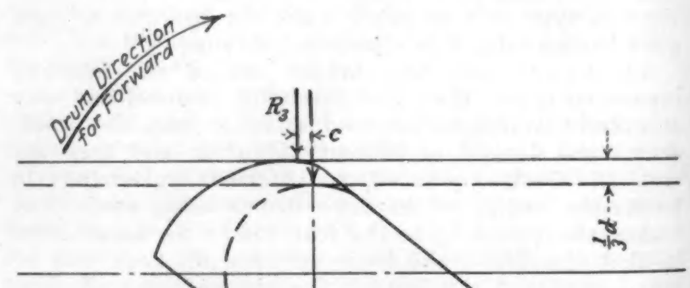

FIG. 4—DIFFERENTIAL CAM
For the Type of Brake Shown in Fig. 2, the Cam Has Greater "Throw" Downward Than Upward. A Differential Cam Is Used So That the Reaction from the Upper Shoe Comes Very Nearly Over the Cam Axis; Hence, the Forward Braking Is Very Little Affected by a Tendency To Close Up the Cam Against the Operator. Slightly Better Braking Is Obtained in the Forward Direction Than in Reverse

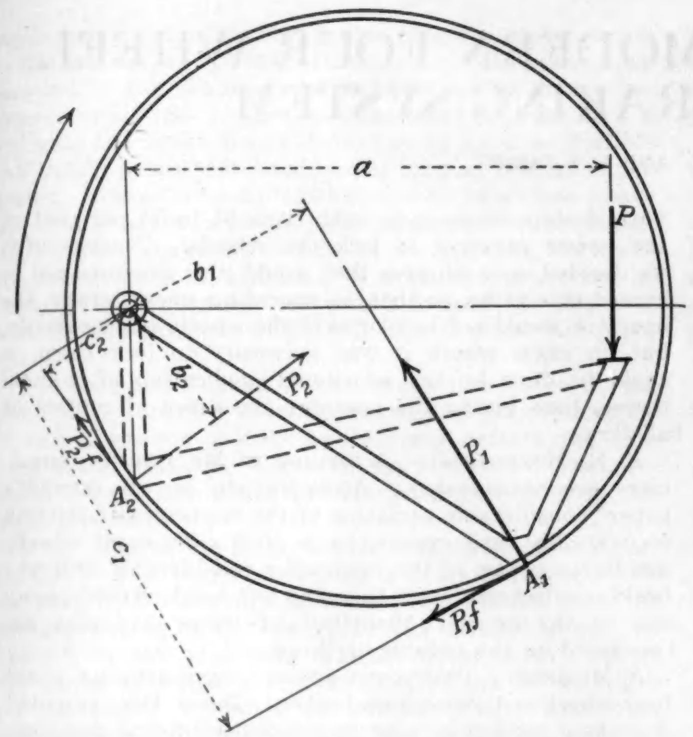

FIG. 5—RELATION BETWEEN BRAKE-SHOE PRESSURES
The Self-Energizing Effect Is the Minimum at the Point A_1, in Comparison with the Effect as Indicated in Fig. 9 of the Paper

(3) The shoes are at all times in contact with the cam, so that the brake will not grab or lock

(4) Due to the powerful braking-action, short levers can be used on the axle. This means that relative movements of the axle and frame will affect the braking action or adjustment very slightly; also, less reduction is required between the operator and the brake. This eliminates the twist and spring in rods, levers and shafts that are only too often very light for the duty imposed on them

(5) Due to the complete contact, long life of lining is obtained and the need for frequent adjustment is less

(6) The two shoes are alike, which is an advantage from both a production and a service standpoint

Mr. Burkhardt, in his Fig. 9, has given a diagram showing the relation between the pressures acting on a conventional shoe-brake. I offer Fig. 5 in which the point A_2 is taken nearer the hinge-pin. His equation $Pa = P_1 b_1 - P_1 f c_1$ applies. This can be put in the form $P = (P_1/a)\ (b_1 - fc_1)$. The self-energizing effect is represented by the value fc_1. For all practical purposes, the value of f can be assumed as constant for the length of the shoe. At the point A_2, the equation above becomes $P = p(P_2/a_2)\ (b_2 - fc_2)$. It may be seen from my Fig. 5 that b_2 is only slightly less than b_1, but c_2 is very much less than c_1. In other words, the self-energizing is the minimum at the point A_2. However, the leverage is greatest here, so that the normal pressure produced by P may be about the same as at A_1. At the cam end, the reverse is true. In the case of the upper shoe, the greatest self-energizing effect for forward braking occurs at the hinge-pin end.

With the braking problems that we now have, self-energizing action is necessary. Since the use of pneumatic tires on trucks, we have been limited in drum diameters. If we adhere to the old-type shoe-brakes, they will require more than a mechanical application.

In Mr. Burkhardt's Fig. 10 we may locate the pivot-pin so that the self-energizing effect is more noticeable and the normal pressures will be greater for the same value of force applied, P. The pin will also have to be located to give as nearly uniform wear as possible over the length of the shoe. A brake of this type can be made very sensitive but, if not carefully laid out, it is likely to be troublesome. It certainly would require accurate machining. Whether a brake of this type could be controlled by other than mechanical means is a question and, of course, a brake suitable for all front-wheel installations should be adaptable to any method of application desired. Further, a large arc of contact is not possible.

I should like to suggest that publicity be given to the importance of correct design of the linkage operating the brakes. In many cases, this is given no consideration by the truck builder. It is a very easy matter to locate the intermediate shaft so that the variation in the adjustment for varying loads will be very little, but this precaution is often overlooked. It is also fairly common to use 1-in. shafts to transfer the braking force from one side of the chassis to the other. This, with flimsy levers, allows considerable stretch. To find that one-third of the pedal-travel is due to stretch is not at all uncommon. If a careful study is made of Mr. Burkhardt's article and a practical linkage is installed, very satisfactory brakes can be obtained.

R. EKSERGIAN[21]:—The problem of a varying distribution of pressure along the periphery of a brake-shoe is one of equal interest to railroad mechanical-engineers. An elementary analysis is given of the railroad type of brake, an equivalent brake-shoe being shown in Fig. 16 of Mr. Burkhardt's paper; but I do not agree with the analysis submitted by Mr. Burkhardt on this particular phase of the subject. The primary error is in the omission of the very important horizontal component at C in Fig. 16, which, in a first approximation, balances the total friction force at the periphery of the shoe. Mr. Burkhardt states that the sum of the horizontal components must be zero; but, in Equation (9), he omits the horizontal component at C.

Referring to Fig. 16, if we let R equal the horizontal reaction at C, we have the following equations of equilibrium:

$$(P_1 + P_2)\cos\alpha + f\,(P_1 - P_2)\sin\alpha - P = O \qquad (17)$$
$$f\,(P_1 + P_2)\cos\alpha - (P_1 - P_2)\sin\alpha - R = O \qquad (18)$$

and, taking moments about the center of the brake-band, to eliminate the moments of the normal components,

$$(P_1 + P_2)\,fr - Ra = O \qquad (19)$$

The unknowns are P_1, P_2 and R, with the required three equations for a determinate solution. Substituting for $R = (P_1 + P_2)\,f\,r/a$ in Equation (18) we have

$$(P_1 - P_2)\sin\alpha = (P_1 + P_2)\,f\,(\cos\alpha - r/a) \qquad (20)$$

which is an equation considerably different from Equation (14).

MR. BURKHARDT:—Mr. Eksergian's conclusion is incorrect. To prove this let us take a case that would give very good proportions, namely, $r = \cos\alpha$. After substituting this in Mr. Eksergian's equation, we obtain $(P_1 - P_2)\sin\alpha = (P_1 + P_2)\,f\,[\cos\alpha - (a\cos\alpha/a)]$.

It will be seen that from this follows $(P_1 - P_2)\sin\alpha = O$, or $P_1 = P_2$; but this obviously is wrong.

[21] Engineering department, Baldwin Locomotive Works, Philadelphia.

DEVELOPMENT OF A MODERN FOUR-WHEEL MECHANICAL BRAKING-SYSTEM

BY J. R. CAUTLEY[22] AND A. Y. DODGE[23]

ABSTRACT

BECAUSE of the increase of traffic on the highways in the last few years, retardation has become the most vital function of car operation; and safe retardation is as necessary as rapid retardation. Good brakes are as essential as a good engine. Becoming convinced of the many attendant advantages of four-wheel brakes, the authors began an intensive study of braking, the results of which are outlined.

The features of construction of the Bendix-Perrot standardized four-wheel braking-system, which include (*a*) standardized and improved controls, (*b*) standardized brake-shoes and (*c*) a simplified brake-operating layout or hook-up, are described and illustrated and the advantages to be obtained with these improvements are summarized. [Printed in the July, 1925, issue of THE JOURNAL.]

THE DISCUSSION

V. W. KLIESRATH[24]:—I believe that the three-shoe self-energizing brake has some advantages and probably will help considerably in the lighter cars, but it will only partly meet the requirements of the heavier cars, trucks and motorbuses. With regard to the various designs of the internal shoes, we have been experimenting with the booster type of power brake in connection with existing brake mechanisms and find that there is considerable latitude in the present designs for the employment of power application. As for the self-energizing shoe, I cannot say exactly what will happen when the greater pressures are applied, because we have not had any experience in adapting them to power application. A great many variables are met with in brake construction, such as the effect of grease, oil, water and heat upon the linings or the shoes, which materially affect the unit pressures necessary to stop any vehicle within a given distance.

We feel that the time is at hand when power or pressures greater than can be applied manually are necessary, especially in the heavier vehicles, considering the ever-increasing road congestion. Therefore we have devoted all of our time to developing what in effect is a booster brake interposed in the brake-rod between the brake-pedal and the equalizing-bar. It is a double-acting power cylinder actuated on the vacuum principle and connected with the intake-manifold of the engine. The operation of this brake is comparatively simple as regards its functioning, its maintenance and the ease of installation. It is normally suspended in a vacuum and has no external control-valves, tanks or other elements, and the cylinder becomes its own reservoir.

The operating valve is located in the piston and the cylinder is so designed that it does not do all the work necessary to lock the wheels. The size was determined upon after testing a great many cars and finding that normal stops were made with from 65 to 75 per cent of the power required to lock the wheels. Consequently, we decided upon an area that would give pressure not to exceed this value, so that, in operating under power, the operator would not lock or skid the wheels unnecessarily, but, in cases where it was necessary to lock them, it could be done by the additional application of manual power, thus giving the operator the sense of control at all times.

F. E. MOSKOVICS[25]:—According to Mr. Cautley, equalizers are unnecessary. According to Mr. Burkhardt's paper[26] considerable variation of the coefficient of friction occurs. My own experience is that right-hand wheels, due to the crown of the road, offer considerably different braking-effect problems than the left-hand wheels, partly due to the greater quantities of water and dirt encountered on the outside of the road.

A MEMBER:—Two years ago we were arguing about four-wheel and two-wheel brakes. Today the argument is getting perilously near to compensation and non-compensation. In the brake layout that Mr. Cautley has shown, which has no compensation, it seems to me that, while there is absolutely no need for compensation from side to side, there is a very definite reason for compensation from end to end. There is a fairly definite relationship of the loading fore and aft and, if that can be dealt with so that it will be impossible under any conditions to skid the front wheels before the back ones are locked, one will have a little more chance of dodging the hereafter.

A. Y. DODGE:—If you feel that you must use compensators, I believe that the place to use them is between the front and the rear ends, as suggested. We have used them there; in fact, when a customer wants them all-around we will use them all-around, but we advise against any because we have greater safety when we use none and also have a simpler hook-up. As was shown in the drawing, you can lose any part of that braking system and still have at least two brakes remaining. When compensators are used, there is not that factor of safety.

B. B. BACHMANN[27]:—Will Mr. Cautley give us some information relative to his recommendations for the division of power between the front and the rear wheels with respect to the weight distribution? Assuming that the distribution is 40 per cent on the front and 60 per cent on the rear wheels, what would be his recommendation as to division of braking power?

MR. DODGE:—Ordinarily we recommend that the braking proportion front and rear shall be directly proportional to the weight front and rear. When the weight is divided 50-50, the braking effort recommended is 50-50. On some cars we can go higher than that in front for racing men and expert drivers, but for the public the safest proportion is 50-50.

E. C. WOOD[28]:—In our analysis of the present-day maintenance costs on the Pacific coast, particularly in the San Francisco territory, we have found that the brake assemblies in our automotive equipment cost considerable; that is to say, the man-hours required for surfacing, relining, replacement of drums and adjustments are high. I attribute this to the equalizer layout, brake-

[22] M.S.A.E.—Bendix Engineering Works, Inc., Chicago.

[23] M.S.A.E.—Chief engineer, Perrot Brake Corporation, South Bend, Ind.

[24] M.S.A.E.—Consulting engineer, New York City.

[25] M.S.A.E.—President and general manager, Stutz Motor Car. Co. Indianapolis.

[26] See THE JOURNAL, July, 1925, p. 65.

[27] M.S.A.E.—Engineer, Autocar Co., Ardmore, Pa.

[28] M.S.A.E.—Superintendent of transportation, Pacific Gas & Electric Co., San Francisco.

bands being out of round, faulty leverage systems and to the low carbon-content of the drums, which has been responsible for much of the trouble, as the drums become scored and require considerable resurfacing. I feel that the brake-drums should be as hard as possible and should retain this hardness as long as possible when heated. Brake-lining material should be of a close weave and should have, so far as possible, a uniform coefficient of friction throughout its life, as we find that the liners are not uniform in thickness. I think that much can be done by the lining manufacturers toward the improvement of equalization, which will help to solve this problem.

The four-wheel brake is practically new to us on the Coast. Our country is mountainous and the topography of San Francisco is hilly, hence brake defects and failures are a material factor in maintenance. The proposed brake-drum-dimension standard is a step in the right direction.

C. M. MANLY[29]:—I am not a protagonist of any particular kind of brake or braking system, but it seems to me that in any attempt to work out a system based on the application of the brakes by any manual power, we are confronted by a very difficult situation in that we are trying to utilize a very small effort which we multiply by either wrapping or self-energizing brakes or through the utilization of high frictional coefficients, all of which come back to factors that vary tremendously with temperature, grit, water and everything of that kind. The power brake certainly has a great advantage in that it applies a large force without depending on multiplying factors that vary greatly with all of these conditions over which we have no control.

If we could have, for example, metal-to-metal brakes, a low coefficient and a large force that we could control to apply those brakes, we would have much less variation in braking effect. That strikes me as being very important in connection with the possible great advantage that any power system of braking has over a hand or foot-operated system.

CHAIRMAN W. R. STRICKLAND[30]:—Mr. Manly's point is well taken but, unfortunately, competition and expense will force the trend the other way for passenger-car business.

C. L. SHEPPY[31]:—Brake-drum forgings of 0.40 or 0.50 per cent carbon steel have proved very satisfactory with rather hard lining. Nowhere nearly so hard a lining can be used in the ordinary soft low-carbon stamped drum as with a high-carbon-steel drum. I do not know what effect the metal liner would have on a steel drum. The chances are that the drum would have to be rather high in carbon even if it were necessary to carbonize the drum and grind it afterward. Years ago our company made some extensive experiments with cast-iron brake-shoes and steel drums, and I hope that the results obtained today with metal-to-metal brakes are more satisfactory than ours were.

MR. MOSKOVICS:—We have before us, in the bicycle coaster-brake, a very good example of a metal-to-metal brake. It is 2 in. in diameter, and you know the work it has to do. The shell is of low-carbon steel, carbonized and hardened. The three shoes, which are small in diameter, are of high-carbon steel drawn to spring temper. They run in oil and practically never wear out. I have often wondered why, when we see so much intelligence applied to the brake problem, we do not have this simple and efficient form of mechanism that has a constant coefficient of friction, does not wear out and answers all of these other questions.

J. R. CAUTLEY:—Power application undoubtedly will permit the use of a metal lining, if one is brought out that proves adequate. Whether they are used as servo brakes without power application or with power application, the three-shoe brakes in the Bendix-Perrot system are of real advantage, because of their greater lining area and their even pressure-distribution. We cannot equalize completely without equalizers but we can come near it with considerable less mechanism, and, as I tried to bring out in the paper, equalizers do not equalize the friction in the brakes.

We should like to see the variations due to self-energizing and to lining conditions reduced, and have done what we can to reduce them by protecting the brake and keeping out mud, water and moisture so far as possible, for these things cause the greatest variations. Because of this protection, Mr. Moskovics' first remarks no longer apply in any large measure. We would like to see high-carbon drums used, but very few people will pay for them.

A MEMBER:—In Mr. Cautley's brake control the four brakes are applied simultaneously by the pedal and the rear pair only by the hand lever. That apparently provides two sets of brakes but it does not fulfill one condition that is of great importance where a considerable amount of work is done in hilly country, that is, the desirability of alternating independent sets of brakes. The difficulty of doing that on the ordinary car is responsible, I believe, for a considerable amount of crankcase oil-dilution as the result of the use of the engine as a brake. It is possible to arrange a hand brake of sufficient area and effectiveness to permit of its application independently of the foot brake so that by alternation a period is allowed during which the brakes previously used may cool off.

MR. CAUTLEY:—Mr. Strickland has just said to me that such a demand would necessitate the use of eight-wheel brakes. As a matter of fact, it comes down to this, that if you use four-wheel brakes you have half the heat on each drum that would result from the use of two-wheel brakes. Only a very hilly country would necessitate the alternation of four-wheel brakes with another set. You cannot induce the manufacturer to make nor the public to buy cars equipped with two totally independent four-wheel braking systems, as that would entail an independent set of drums and increase the cost beyond all reason. Moreover, it is not necessary. What we have had heretofore has been rear-wheel brakes, and we have tried alternating the hand and the foot brakes on the same drums with the idea of keeping them cool. By putting on four-wheel brakes we have more than doubled our effective cooling-area. I wish to emphasize this point. Not only is there double the physical area, due to the two front-wheel drums, but the rear drums are not covered on the outside with an asbestos insulation in the form of brake-lining. Finally, the front-wheel drums are in a better position for cooling than are the rear-wheel drums. Hence, we get more than double the cooling effect. Alternation of the brakes is not necessary except under conditions that would be so extreme that you would have to buy a caterpillar.

CHAIRMAN STRICKLAND:—I think that the driving public has been educated, especially in mountainous country, not to rely too much on the brakes when descending steep hills but to use the engine as a brake.

[29] M.S.A.E.—Consulting engineer, Manly & Veal, New York City.

[30] M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

[31] M.S.A.E.—Chief engineer, Pierce-Arrow Motor Car Co., Buffalo.

Dilution is very slight, I think, when descending with the spark switched on. Those are part of the instructions seen on signs, even on the tops of many of our mountains.

CYLINDER AND ENGINE LUBRICATION

BY A. LUDLOW CLAYDEN[32]

ABSTRACT

DATA regarding the condensation of water on engine-cylinder walls when running the engine at comparatively low temperatures were presented by the author in a previous paper to which he refers. These experiments showed that no water would be deposited when the cylinder-wall temperature exceeded 110 deg. fahr. but that the rate of deposition increased in direct proportion to the drop of temperature below 110 deg. fahr.

His present paper describes laboratory tests of an engine equipped with a steam cooling-system, the object being to study the effect upon dilution of high cylinder-wall temperatures. The results show that a sharp reduction in dilution occurs as the boiling temperature is reached, and that the amount of dilution at temperatures of 212 deg. fahr., or more, is much less than would have been anticipated from the results obtained at temperatures below 212 deg. fahr. The author then points out that high cylinder-temperatures reduce dilution to a negligible quantity without introducing any apparent disadvantages.

The fact that the elimination of dilution inevitably will produce lubrication troubles, due to the higher viscosity of oil which will prevail, is emphasized, and various methods by which oiling systems can be modified so as to approach nearer to the ideal condition are suggested. [Printed in the July, 1925, issue of THE JOURNAL.]

THE DISCUSSION

RALPH L. SKINNER[33]:—No doubt exists that steam-cooling, because of increased cylinder-wall temperatures, will reduce dilution under favorable operating conditions. During winter operation, however, the low temperatures are conducive to a more rapid accumulation of the diluent in the crankcase.

The tests cited in Mr. Clayden's paper were run under favorable conditions. The carbureter was not unnecessarily enriched as is the custom in the ordinary operation today. In average operation, rapid acceleration is demanded, which necessarily requires a richer adjustment of the carbureter than would be required for a constant speed. Also, when the choke is used excessively before any heating of the cylinders or pistons takes place, it appears that the conditions cited in Mr. Clayden's paper would have no effect on the dilution in the crankcase.

A number of tests were made recently on several water-cooled cars in Minneapolis, under severe winter conditions, to determine the advantage of heating the oil in the crankcase. While it was shown that this aided in lubricating the cylinders more quickly, it did not reduce dilution appreciably. Considerable time was also spent in making tests with air-cooled engines, which warm-up rapidly.

In air-cooled engines, the cylinder-temperature runs from 300 to 350 deg. fahr. at the ring travel, and from 400 to 450 deg. fahr. at the combustion-chamber, the temperatures being taken in the cylinder-wall 1/16 in. from the inside surface. Dilution rapidly built-up to between 50 and 60 per cent under normal usage, and a dangerous amount of water was collected. In one four-cylinder air-cooled car that was run from Flint, Mich., to Detroit, in February, 19 per cent dilution and 4 per cent of water accumulated in the crankcase oil in 70 miles. Surely the temperature of the cylinder-wall in this instance was considerably above that of the boiling-point of water.

In substantiation of the fact that dilution is the governing factor in cylinder-wall wear, a considerable number of tests have been made in summer operation of tractor engines in California. It was necessary to replace piston-rings in 30 days on a tractor engine in which dilution would accumulate to 30 per cent in 10 hr. of operation, and the oil was thinned down at the end of 20 hr. so as to necessitate a change. A device was installed which prevented dilution, and this same tractor has been operating for nearly 4 years without the necessity of changing a single piston-ring in that time. The cylinder-wall temperatures in this tractor approximated those obtained by steam-cooling, as it operated under atmospheric temperatures of from 107 to 115 deg. fahr. in the field.

It appears on the face of it that a certain amount of combustion gases blow-by the piston-rings, are condensed on the crankcase wall, and then find their way into the crankcase oil. The gases may be in a volatilized or gasified state when they pass the pistons and the cylinder-walls, but they condense very quickly on reaching the lower part of the crankcase.

In his paper, Mr. Clayden states that the ordinary engine is protected by crankcase dilution! The apparent advantage is that diluted oil is not readily congealed, which facilitates starting in cold weather and reduces the time interval required for it to be forced to the bearings. When dilution is admittedly harmful, however, it is not logical to tolerate even a small percentage of the contamination, especially in view of the quantity of fuel that must pass the pistons before reaching the crankcase. Therefore, not only does the oil-film protecting the cylinder-walls contain a much higher percentage of dilution than the oil in the sump but, being already diluted, the oil-film's disintegration is accelerated so that under starting conditions it is partly if not entirely washed away. Excessive piston and cylinder wear results.

In recommending a very heavy oil during the winter season, Mr. Clayden has not stated what will happen to the cylinders during the first two or three starts before the oil has become sufficiently diluted to circulate freely. Dilution will build-up rapidly, it is true, and the other extreme will soon be reached. With no means of controlling dilution, the crankcase oil in the average engine will soon show an alarming percentage of fuel, which renders it inadequate for lubrication. Therefore, it seems much more desirable for all engines to be designed to include a simple layout for eliminating dilution. This course, which is already being followed by some manufacturers, permits the winter use of lighter grade oils with lower pour-tests. Thus, not only will cold-weather starting be facilitated, but perfect lubrication will be

[32] M.S.A.E.—Chief engineer, gas engine research, Sun Oil Co., Philadelphia.
[33] M.S.A.E.—President and manager, Skinner Automotive Devices Co., Detroit.

made possible by maintaining good viscosity of the lubricant.

A. L. CLAYDEN:—I think it is very probable that, in considering his experiences with air-cooled engines, Mr. Skinner has confused cause and effect. It has been my experience that the gasoline leakage into the crankcase of air-cooled engines is very much greater than is usual with water-cooled engines. I attribute this to the fact that the piston-clearances are usually much greater, while it also seems reasonable to suppose that a cylinder operating at 300 deg. fahr. or more has a much better chance of running out-of-round than one which is held at lower temperatures. The large amount of dilution found after 70 miles of running strongly encourages me to believe that both the water and the gasoline reached the crankcase principally from blow-by.

The elimination of dilution, however it may be obtained, will necessitate a reconsideration of lubrication systems because the lightest oils that would be really satisfactory when the engine is warm would, if entirely free from dilution, have an excessive viscosity in extreme cold. Of course, use of rather lighter lubricants would naturally follow the elimination of dilution; but, in my opinion, it is not at present possible to take complete care of the situation by means of oil alone.

H. M. RUGG[34]:—In the study of the dilution problem, it seems that very much depends upon the condition of the fuel mixture as it enters the combustion-chamber, and much difference of opinion exists as to the actual state of the mixture at that time. The term "vaporization" is accepted and defined in various ways by different people; the dictionary definition of the word would cover mixtures varying from a dry gas to a mixture containing floating moisture. In a paper entitled the Volatility of Internal-Combustion Engine Gasoline,[35] F. A. Howard has stated that gasoline ordinarily possesses sufficient volatility to maintain the condition of a gas at temperatures below the average intake-manifold temperatures. Manifold condensation seldom, if ever, occurs and cylinder condensation is even less probable. The phenomenon that we call "condensation" is mainly a visual evidence of incomplete vaporization; and, if liquid is found in the cylinders or in the manifold, it reached there as a liquid. We know that liquid is there and what it is doing to the lubricating oil. This would apparently justify the statement that the fuel mixture is never completely vaporized and that always some particles of liquid fuel may be present which can be deposited upon the cylinder-walls.

Two conditions exist within the cylinder that may affect the amount of deposition of liquid fuel; namely, the motion of the fuel mixture in the combustion-chamber and the cylinder-wall temperature. In a turbulent mixture, centrifugal force tends to throw any heavy particles or drops of liquid onto the walls of the cylinder and of the combustion-chamber. In an article entitled the Dilution Process Explained,[36] it is shown clearly how the cylinder-wall temperature may either assist in vaporization or produce the so-called condensation. Judging from all the existing conditions, it seems that no real condensation in the true meaning of that word takes place; but most of the deposition of liquid fuel comes from the accumulation of small particles of liquid which are carried into the combustion-chamber and some of this liquid accumulates even in the intake-manifold due to restrictions of as influenced by manifold design and construction. Any effort to keep the temperature of the cylinder-walls up to a point that will assist in maintaining the fuel in a vapor state naturally will prevent the accumulation of any great quantity of the liquid. It may not change the liquid to a true gas, but it does keep the liquid broken up into very fine particles, so that it can be burned more easily, even though the combustion may not always be complete. As to the time when these accumulations take place, if the cylinder-wall temperature is above that of the dew-point of the mixture, then it will be true that no deposition of liquid fuel would take place during the suction stroke; but, if the cylinder-wall was at too low a temperature, condensation can take place during this stroke as well as during the compression stroke.

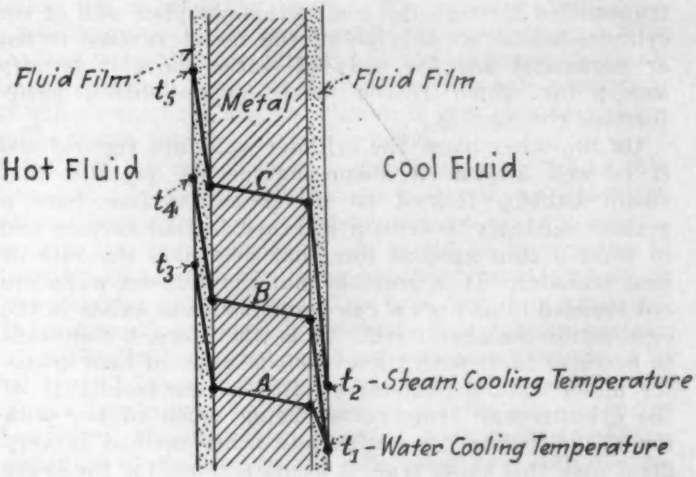

FIG. 6—POSSIBLE RELATIONS OF HEAT TRANSFER UNDER THREE TYPES OF COOLING SYSTEMS

The Three Curves, A, B and C Represent a Circulating Water-Cooled, a Thermosiphon Water-Cooled and a Steam Cooling System Respectively. The First Two Curves Are Based on the Same Outlet-Water Temperature t_1, Which Is Slightly Lower than the Boiling-Point of Water. Due to the Difference in Velocity of the Cooling Medium, the Temperatures on the Inside of the Cylinder-Wall Will Be Different, as Shown at t_3 and t_4, the Latter Being the One for Thermosiphon Cooling. The Corresponding Temperatures for the Steam Cooling-System Are Designated by t_2 and t_5

The prediction of the amount of dilution when using steam-cooling, by projecting a curve developed from the water-cooled-system tests, can hardly be justified if the actual conditions within the engine are taken into consideration. The conductivity of a cooling medium depends upon the character of the fluid and its velocity. When using a circulating water-cooling system, the water is kept in rapid circulation by the water-pump and the rate of heat transfer is comparatively high, with a consequent small difference between the inner and the outer cylinder-wall temperatures. A very appreciable difference in cylinder-wall temperatures exists in a thermosiphon water-cooled engine, as compared with a pump-circulation water-cooled engine, the inner cylinder-wall temperature in the former being much higher than in the latter.

When the steam cooling-system is used, practically no circulation of the cooling water occurs, the amount of the water supplied by the pump being only sufficient to replace that actually converted into steam. It is true that, as soon as boiling of the water begins, the rate of heat transfer is increased; but the construction of the water-jacket is such that only a small amount of ebullition adjacent to the cylinder-walls may occur. The small steam-bubbles will be formed most rapidly where the heat is greatest, which would be practically confined to the combustion-chamber when the piston is at the top of its travel, and by far the largest amount of heat would be

[34] M.S.A.E.—Engineering division, Vacuum Oil Co., New York City.
[35] See THE JOURNAL, February, 1921, p. 145.
[36] See THE JOURNAL, October, 1924, p. 271.

transmitted through the combustion-chamber wall of the cylinder-head. At this point, the metal surface is flat or horizontal and the body of water above it is very small; for which reason small steam-bubbles, easily formed, rise rapidly.

On the other hand, the cylinder-walls are vertical and it is well known in steam-engineering practice that steam bubbles formed on a vertical surface have a greater tendency to remain attached to that surface and to form a thin gaseous film that decreases the rate of heat transfer. It is possible that the cylinder-walls are not exposed to as high a gas temperature as exists in the combustion-chamber itself. It is, therefore, not difficult to perceive that, with these various rates of heat transfer under different cooling-conditions, the possibility of the cylinder-wall temperature being much higher with the steam-cooling than with any other method is very great and, this being true, it would account for the lower percentage of dilution.

Fig. 6 shows the possible relations of heat transfer under the three types of cooling system. The curve *A* represents a circulating water-cooled system; *B*, a thermosiphon water-cooled system; and *C*, a steam cooling-system. Curves *A* and *B* are shown as being based on the same outlet-water temperature t_1, just slightly under that of the boiling-point of the water. Due to the difference in velocity of the cooling medium, the temperatures on the inside of the cylinder-wall will be different, as shown at t_3 and t_4, the latter being the one for thermosiphon cooling. Temperatures t_2 and t_5 are for steam-cooling.

In connection with the oil distribution during cold weather, the statements made would apply very positively if reference had been made to the types of force-feed lubricating-system as used today. These systems have been designed to avoid the troubles experienced from over-oiling. Their use has increased rapidly in the last few years and accompanying this use has come the difficulty in oil distribution. Little or no difficulty is experienced with the splash lubricating-systems. In fact, tests made in reference to the problem of scuffing of aluminum pistons seem to show that the splash lubricating-system will give practically no trouble so far as distribution is concerned.

In reference to the possible jacket temperature at which all dilution would be removed, Mr. Clayden mentions that it seems to point toward a temperature approximating the end-point of the fuel, which he considers improbable. From observations and tests, however, this temperature probably does approach the end-point of the fuel more closely than in the comparison with water, as can be shown by making distillation tests of the diluents removed from crankcase oil. The smaller the percentage of dilution is, the higher up on the distillation curve of the original fuel the curve of the diluent seems to fall.

In connection with the conditions at idling speed, the lower temperature of the oil in the crankcase would not account for the increase in dilution. It was found in Neil MacCoull's tests, that the crankcase temperature, the temperature of the vapor in the crankcase, had a very vital influence on dilution, and this was affected more by jacket temperature than by oil temperature. Even if an oil heater was used, the enriched mixture and cooler cylinder-walls at idling speed would cause more liquid fuel to mix with the lubricating oil than the increased temperature of the oil alone could remove.

Referring to Mr. Jardine's recommendation for special construction of connecting-rod bearings to provide for distribution of high-viscosity oils, this would lead to over-oiling and consequent excessive carbon-formation, a condition that the later designs are intended to avoid.

ENGINE-STARTING TESTS

BY JOHN O. EISINGER[37]

ABSTRACT

RECENT work in connection with the Cooperative Fuel Research is discussed in the paper, which presents data obtained as a result of the recommendation of the steering committee "that the factors contributing to easy starting be investigated." It refers first to preliminary work discussed in previous reports, and then describes the test set-up. This was much the same as that used in the crankcase-oil-dilution tests, the chief difference being the replacement of the carbureter by a single jet mounted in a vertical pipe. The arrangement was such that changes in jet size, jet location, rate of fuel flow, throttle opening and choke opening could be obtained easily. Provision was made for measuring the amount of fuel used in starting.

The test procedure consisted in driving the engine by the dynamometer until conditions became constant, then in turning the fuel on and noting the time required for starting and the amount of fuel used. The information thus obtained is presented in curves and its significance is discussed. Among the factors, the influences of which are shown, are fuel-air ratio, jet size, jet location, spark-advance, fuel volatility, amount of throttling, amount of choking, temperature of jacket water and temperature of entering air. [Printed in the July, 1925, issue of THE JOURNAL.]

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[38] M.S.A.E.—Research engineer, Stromberg Motor Devices Co., Chicago.

THE DISCUSSION

F. C. MOCK[38]:—Mr. Eisinger's conclusions check rather closely with those obtained in our cold-room experimental work. In making comparisons of starting engines with three commonly-used methods of fuel feed, (*a*) priming-jets in horizontal passage of the manifold, (*b*) priming-jet discharging diagonally into the barrel of the carbureter above the throttle, and (*c*) the use of a choke valve in the air entrance of the carbureter, we seemed to find that for given equal manifold pressures and temperatures the starting in each case depended equally upon the rate of fuel feed. That is, within the range of this experiment it made little difference how the fuel was fed into the air stream so long as it was fed in sufficient quantity to yield vapor for a firing mixture. We found that starting appeared to be assisted by producing a vacuum in the manifold by use of the choke or the carbureter throttle-valve.

We also found that, with a cold engine and at low cranking-speeds, a collector jar placed between the carbureter and the manifold to collect all of the unvaporized gasoline made no perceptible difference in starting, which led us to believe that it was only the portion of the charge that was vaporized in the intake-manifold that could be ignited after compression in a cold cylinder. We had found previously that, with the customary type of intake-manifold and at low cranking-speeds, practi-

cally no liquid fuel would reach the valve ports anyway. I believe that these two considerations will help to explain why Mr. Eisinger found no perceptible difference in distribution in his starting tests.

The method adopted by the Bureau of Standards group in attacking this problem of starting by testing one factor at a time is commendable. The simple device that was employed tests the effect of fuel feed only and eliminates the possible complications that might have been encountered in the experimental work had a conventional carbureter been used. I hope that further tests will include measurements of the effect of (*a*) low voltage in the ignition system, as results when the starter is turning the engine over very slowly; (*b*) leakage past the piston-rings and through the valves, for we frequently find that loss of compression makes starting much harder; and (*c*) engine-speed variation between, let us say, 35 and 140 r.p.m., in determining whether the compression in the cylinder is adiabatic or isothermal, for, since we believe that isothermal compression condenses and adiabatic compression assists vaporization, this factor should have a material bearing on the vapor condition in the cylinder.

W. H. CONANT[29]:—I trust that it is pertinent to this subject to refer briefly to the term "viscosity." Viscosity of an oil is accepted by engineers broadly as indicating its lubricating value. We consider that high viscosity gives better or longer lubrication, or that it is the one essential for larger bearing-clearances. Many engineers know, however, that viscosity is only a measure of adhesiveness; it has no relation to cohesiveness, which gives oil its actual lubricating value.

No test for cohesiveness is commonly accepted in this Country. I understand that in England, or elsewhere abroad, some method for measurement of this characteristic has been developed. It would be interesting to take up this point for more extended consideration at some future opportunity. The need for it is apparent. It is claimed, and widely believed, that lubricating oils of a paraffin base have more cohesiveness than those of an asphalt base. Preference has been expressed for the slower breaking-down qualities of paraffin oils under the conditions of automotive practice, such as temperature, yet most of the automobile oils today probably are derived from asphalt-base crudes and the results from their use hardly can be called unsatisfactory. I believe that we need to develop another test-characteristic for lubricating oils.

J. O. EISINGER:—It is gratifying to learn that Mr. Mock, through his own investigations, has checked the conclusions presented in this paper. His approval of our test procedure is particularly appreciated because of his long experience in research work in this field. Some of the suggestions for future work are already in the Bureau's program and will receive consideration.

[29] M.S.A.E.—Assistant to manager, J. G. White Management Corporation; general manager, industrial division, Panhard Oil Corporation, New York City.

OCTOBER COUNCIL MEETING

AT the session of the Council held in Detroit on Oct. 23, the following were present: President Horning, First Vice-President Litle, Vice-President Church, Councilors Burkhardt and Hunt, Past-President Crane, and Vice-Chairman Chandler of the Sections Committee.

Applications for membership to the number of 293 were approved. The resignations of 53 members were accepted, and 317 members were dropped for non-payment of dues accruing Oct. 1, 1924. Four reinstatements to membership were made; also 30 transfers in grade of membership.

The financial statement as of Aug. 31, 1925, showed a net balance of assets over liabilities of $156,249.68, this being $8,342.38 less than the corresponding figure on the same day of 1924. The net revenue of the Society for the first 11 months of the current fiscal year amounted to $198,685.00. The operating expense during the same period was $204,389.60.

From Jan. 1 to Oct. 17, 1925, 732 applications for membership were received, as compared with 578 and 497 during the same periods of 1924 and 1923 respectively. The total number of approved applicants, including Affiliate Member Representatives, who qualified for membership during 1925 up to Oct. 17 was 510.

In connection with the items of budget expense during the current fiscal year, it was estimated that the income of the Society for the year would be about $330,000.

Consideration was given to features of current meetings and early 1926 meetings of the Society.

The opinion was expressed that the Society should initiate a movement to further standardization of wire and sheet-metal gage practice.

Prof. R. M. Anderson was named to represent the Society on the Sectional Committee on Scientific and Engineering Symbols and Abbreviations. H. C. Mougey, chairman of the Lubricants Division, was appointed to serve as a delegate of the Society on the Petroleum Products and Lubricants Committee of the American Society for Testing Materials.

Pursuant to discussion had at the time of the last Production Meeting of the Society in Cleveland, and subsequent conferences of automotive production men in Cleveland and Detroit, action was taken toward establishing a Production Division of the Standards Committee, for the purpose of formulating standards or practices closely related to automotive production. A skeleton organization for the work of the Division has been outlined.

The following Standards Committee appointments, with assignment to the Divisions indicated, were made:

G. H. Adams—Axle and Wheels Division and Ball and Roller Bearings Division
Oscar Froelich—Electrical Vehicle Division
F. G. Klock—Lubricants Division
Vincent Link—Motorcoach Division
D. M. Pierson—Electrical Equipment Division
F. H. Prescott—Electrical Equipment Division
T. E. Wager—Electrical Equipment, Lighting and Storage-Battery Divisions

It is expected that the Society will participate as a sponsor in the work of the Sectional Committee on Pins and Washers.

D. F. Chambers was nominated to serve as a member of the Sectional Committee on Ball Bearings.

The next meeting of the Council will be held at the Benjamin Franklin Hotel in Philadelphia on Nov. 12, the day preceding the Transportation Meeting of the Society there.

The Evolution of the Modern Racing Airplane

By W. L. GILMORE[1]

AERONAUTIC MEETING PAPER

ABSTRACT

A RACING airplane seems to possess a special quality that sets it distinctly apart from the conventional type of airplane; but, unless a person has at least dabbled in its design, he cannot realize the enormous amount of time, effort and ingenuity that has been expended by the designers who have made these super-speed airplanes possible. Therefore, an outline is given of the procedure adopted in designing and producing a specific model of racing airplane, as well as an outline of the yearly progress made in development.

The first procedure is to allocate the work to the various members of the engineering organization. Finally, a type of design is chosen after a series of engineering conferences, and the design section studies the detail design of the component parts. A wing section that is adapted to the design already chosen is developed, and an accurate weight estimate is made of each unit part of the complete airplane. Knowing the weights, the wing and the tail areas are calculated and a new layout is made preparatory to determining the sizes of the various members. When these sizes become known, a fairly definite idea has been obtained as to the over-all dimensions of the airplane. A model, one-twelfth the size of the desired airplane, is constructed from special drawings; it is used for experimental purposes in the wind tunnel, and has a threefold purpose. First, it gives the designer a true picture of the completed airplane; second, it affords a means of ascertaining by wind-tunnel experiments the maximum speed of the airplane; and third, the controllability and the stability of the racing machine can also be determined by the wind-tunnel-model test. The final design of the airplane and its component parts can then be completed.

Dividing the airplane's component parts into groups, the author discusses present practice in its relation to each group under the headings of wings, tail surfaces, landing gear, fuselage, powerplant and control system.

SPECIFICATIONS made by the Army or by the Navy in contracts for racing airplanes cover a guaranteed high speed and a guaranteed landing speed; freedom is accorded the contractor as to how the guarantee shall be realized. The company I represent is constantly studying the problem of how to increase airplane speed and is in a position to guarantee, not only a speed much greater than that realized by previous models, but is able to equal or better its guarantee.

In the design of a new racing type of airplane, the first procedure is to allocate the work to the various departments of the engineering organization. The general arrangement and type of design are finally determined by the design section, which lays out an extended series of different types, and studies are made from the standpoints of weight, resistance and structural analysis. At this stage of the design, very close cooperation within the engineering organization is necessary, because it is at this stage that the airplane is "born," and it is here that its major characteristics are determined. No turning in the ways can be made after this part of the work is completed, since the amount of time available is extremely limited.

In 1923, during the preliminary design of the Pulitzer racing airplane for the Navy, more than eight separate types were laid out before the final design was chosen. Included with these were a triplane, several biplanes, two sesquiplanes and a monoplane. Metal construction was contemplated for the wings, as well as wood construction. Folding wheels that could be retracted into the lower wing were tried on the sesquiplane. The final design was a compromise between two others, both of which offered excellent possibilities.

Usually, it is possible to decide between two or more tentative designs by comparing their speed with that of the last year's model, on a relative basis. Finally, a type of design is chosen after a series of engineering conferences. The work is then definitely distributed to the design, the structure, the aerodynamical, the weight and the propeller departments or sections. The design section busies itself with studies of the design of detail parts, for a great amount of work must still be done before the final-design drawings can be got under way.

First, a wing section must be developed which will be adapted to the design that has been chosen. If a monoplane is contemplated, a thick wing is necessary; if a braced biplane, which is a type that we have been using for the last 5 years, is desired, a wing section of medium thickness is required. In the early days, when factors of safety were as low as 7 or 8, a thin wing-section was possible; but, when a factor of safety of $12\frac{1}{2}$ is used, a thicker wing is needed to provide the required strength and rigidity.

In developing a new and better wing-section, we usually begin with several good sections and develop a "family" from them; that is, we incorporate certain variable features that are known from previous research and study to have low drag-characteristics. To facilitate the testing of these experimental sections, a special modeling machine has been constructed which allows us to lay out, construct and test in the wind tunnel, a model that is accurate to 0.002 in., the time needed for this being only 6 hr.

Experience has shown that the combination of wing loading and high speed is such that a racing airplane will fly practically at the angle of minimum drag. Since the maximum lift determines the wing area needed, it can be seen readily that the section having the highest ratio of maximum lift over minimum drag is the best speed-section. By taking wind-tunnel readings for these extreme angles only, the amount of research work needed on wing sections is reduced to the minimum.

WEIGHTS AND SIZES OF PARTS

As soon as a wing section has been decided upon, an accurate weight estimate of each unit part of the complete airplane is made by the weight section. Here, again, our past experience stands us in good stead, be-

[1] Curtiss Aeroplane & Motor Corporation, Garden City, N. Y.

cause we have exact records for all machines previously constructed of the parts-weights of the complete machine. These records permit us not only to estimate accurately the weights for new designs, but they give us excellent records of the comparative weights of the various types of construction. This weight estimate is, we believe, equally important as is the aerodynamical study of the design; for, upon it depends the final acceptance of the airplane. If the weight estimate is too low, the landing speed will exceed the guarantee. If the weight estimate is too high, too much wing area will be necessary and high speed will be sacrificed. Here, also, close cooperation between the design, the structure and the weight sections is essential in order that the weight estimate will represent, as closely as possible, the finished article.

After a parts-weight and a total airplane-weight have been determined, the weight section prepares a weight schedule, or "bogey," which is posted in a conspicuous place in the engineering department. To make certain that these weights will be fulfilled, the weight of each part is calculated carefully and the drawings cannot be released to the shop unless the bogey weight is achieved or bettered. In case of overweight, a redesign is called for automatically. As each part is constructed in the shop, the weight section obtains the true weight and compares it with the estimated or release weights. Although the foregoing method of weight control is both tedious and costly and has required years to perfect, the design of a racing airplane would be impossible without such a method, since it is designed on close margins and must meet our contract guarantee with certainty.

Having the weights, the wing and the tail areas are calculated and a new layout is made preparatory to the determination of the sizes of the various members. These sizes are determined by the structure section, working in conjunction with the design section. Not only are all major parts such as struts, wires and beams analyzed; but also all fittings, attachments and minor parts. If doubt in any sense exists about a part difficult to calculate, the part in question is tested to destruction in a manner that simulates the actual conditions in the airplane.

Upon reaching this stage of the process, a fairly definite idea has been obtained as to the over-all dimensions of the airplane. The engine, the oil and the fuel tanks and the pilot have been crowded into a fuselage of cross-section but slightly greater than that of the engine. A wind-tunnel-model drawing is laid out, and the model is constructed in the model shop. This model is carved by hand from seasoned mahogany and, although but one-twelfth the size of the full-size airplane, it is as exact a duplicate as it is possible to construct. The model serves a three-fold purpose. First, it furnishes the designer with a true picture of the completed airplane. An old adage has it that: "If it looks well, it will fly well." No doubt "looks" are a combination of reasoning, comparison and experience. At any rate, an experienced designer is able to give to a racing airplane a certain touch of something that undoubtedly adds several miles to the top speed. If the nose cowling does not appear to be exactly right, the designer uses modeling clay to form a new nose that suits the sixth sense which he calls "looks."

Second, the model is tested in the wind tunnel to check the calculated high speed of the airplane. Thus far, it has not been necessary to decide what would need to be done in case the original calculations proved to be wrong at this stage; but, considering the amount of time allotted, it would be exceedingly embarassing if any major changes were necessary.

Third, and perhaps most important, the controllability and stability of the completed airplane is also determined by the wind-tunnel-model test. Here, again, data from past performances are made use of because, to a large extent, controllability is a relative matter and, unless comparative data are available, the wind-tunnel tests are of minor value only. If it is deemed necessary, the control surfaces are changed sufficiently to provide the desired flying qualities.

Regarding the actual procedure relating to the final design of the airplane and its component parts, I will now present an outline of the design progress made during our experience in the construction of racing types of airplane and will use the same grouping of parts as that used by the engineering department.

Wings and Tail Surfaces

The present cellular wood-covered wing-construction was used first on the 1920 Gordon Bennett racing airplane. The covering was made up of two layers of spruce planking, laid diagonally, and was used at that time as a substitute for the fabric covering now used on the conventional airplane. Difficulty had been experienced in having the fabric blow off at speeds of about 200 m.p.h. Spruce planking was also used later on the 1921 Type CR-1 racing airplane of the Navy, not only as a covering but also as a strength member similar in principle to that of the plates of a plate girder. The web members of this cellular construction were solid on the Type CR-1; but, in 1922, on the Army racing airplane, tests proved it to be possible to use lightening holes in some of the members. In 1923, the construction was modified further on the Navy racing airplane, which later held the world's speed record of 266 m.p.h. By changing the angle of the grain of the spruce planking somewhat, this was found to improve its strength considerably and allowed us to use a very light internal construction of spruce-planking webs and light capstrips, Only the two main beams were of solid spruce.

The interplane bracing on the 1921 Navy airplane was of the conventional type of N-strut and external fittings. On the 1922 and the 1923 jobs, all fittings were sunk into the wing and the N-strut was changed to have the present I-beam section, thereby reducing the head resistance considerably. To reduce further the head resistance caused by the interference of the body, the wings and the "cabane," or center-section struts, the wings on the 1923 racing airplane were stubbed into the fuselage in a manner much like that in which the wings of a bird attach to its body.

The tail surfaces on the CR-1 airplane were of steel construction, fabric covered, and external brace wires were used to support them. We changed to a cantilever tail in 1922 and, to assure rigidity, the fixed surface was covered with the spruce diagonal planking similar to that of the wing construction. The movable surfaces on all jobs have been of metal construction, and were formerly of steel; but, on the last two jobs, the ribs were fabricated from duralumin to reduce the weight. All control horns are encased in the stern end of the fuselage.

Landing Gear

The two-strut landing-gear used on the 1922 and the 1923 airplanes originally was proposed to the Navy in 1921; but it was not finally accepted until 1922 by the Army. An extended study of wheel fairings was also made in the wind tunnel in 1923, which resulted in the development of the present type in which the cloth

covers the complete wheel and is doped into place. As used on the present racing airplanes, the resultant landing gear presents an exceedingly clean appearance. The high safety-factor employed in 1923 caused us to change to the internal shock-absorbing wheel, and this allowed us to run the main forward lift-wire from the landing gear directly to the wing structure. The resulting structure was very light and very rigid.

The early racing airplanes had steel leaf-springs of the automobile type for use as tail skids; but, in 1922, we changed to the use of a laminated-hickory skid that absorbs the shock much better and is easier to "fair."

The designer of the float landing-gear, which converts the land type of racing airplane into a seaplane, concentrated his effort toward the attainment of a rugged, seaworthy type of construction. Past European experience has shown that the majority of the difficulties of seaplane racing, especially in the case of the Schneider Cup Race which presents numerous water hazards, have had to do with the float landing-speed. Our designers felt that a slight increase in landing-gear bulk caused by rugged construction would be readily offset by the marked increase in the safety of landing and the lesser possibility of leakage during the anchoring-out trials. This contention was borne out by the results of the 1923 Schneider Cup Race in which our Navy won both first and second places in Curtiss CR-3 machines, and decisively broke the world's seaplane speed-record. The floats gave no cause for anxiety.

In the design of the floats, we have followed almost exactly the type of construction that has been developed during our many years of float and boat construction. The most marked deviation has been in regard to the angle of the bottom V. On the older service-design, in which the power available was rather limited, a relatively flat bottom of about 155 deg. was necessary; but, when landing, these flat bottoms were very poor shock-absorbers. As more and more power became available for get-away purposes, and as the seaplane landing-speeds became higher and higher, we were able to increase the angle of the V and thereby to decrease the shock of landing. The V-angle of the 1925 seaplane has been decreased to 120 deg.

All the fuselages have the monocoque construction in which laminated-spruce planking is used to form the skin; until 1922, the engine mounting and a part of the fuselage proper were of the same type of wood construction. In 1923, because of changes in the landing-gear and due to increased safety factors, the fuselage forward of the fire wall was changed to high-tensile-strength steel-tubing construction. It has been found far superior to the old type of construction if for no other reason than that of improved accessibility to the powerplant. The pilot sits well down in the fuselage; only part of his head is exposed, and it is protected by the triplex glass windshield. With the adoption of parachutes by both the Army and the Navy and their use on the 1925 racing airplanes, a special hinged cockpit-cowling has been devised that allows the pilot to leave the airplane readily in case of necessity and yet allows as small a cockpit opening as in previous years.

Powerplant

Although airplane design has advanced by rapid strides in the last 4 years, it has in no way overshadowed the advancement in engine design. Starting in 1921 with an engine capable of developing 412 hp., the amount of power was increased as follows: In 1922, to 470 hp.; in 1923, to 510 hp.; and, in 1925, to 619 hp. These power increases were accomplished along with a gradual reduction in weight until, in 1925, the V-1400 engine is even lighter than was the D-12 engine of 1921, although the power difference is more than 200 hp.

The early airplane propellers, until 1923, were made of wood; but at about this time the Curtiss-Reed metal airplane-propeller was being developed. In fact, an experimental metal propeller was carried as hand baggage from Garden City to Detroit in 1922 with the hope that it would be used in the Pulitzer race, but it was not accepted. However, in 1923, at St. Louis, metal propellers were used and were welcomed in aeronautical circles because they undoubtedly were responsible for an increased high-speed of from 5 to 10 m.p.h.

Notwithstanding the marked improvement in the design of metal propellers that has extended over the last 3 years, it was believed by the designers that the ultimate improvement had not yet been attained. This contention has been well borne out by the results obtained with the new solid forged type of duralumin propeller that was constructed for the 1925 racing airplane. The engine hub is a part of the propeller itself and this not only saves considerable weight but it allows us to construct true thin-blade sections that extend in a true helix to the very hub of the propeller. Undoubtedly, this type of design will provide the maximum possible propeller efficiency.

The radiators on the early machines were the best that were obtainable at that time and were of the flat-plate type; they were secured to the sides of the fuselage and were faired-in as much as possible. The Lamblin radiator was introduced in this Country at the time of the construction of the CR-1 racing-airplane, and two of these barrel-type Lamblin-radiators were located between the front and the rear landing-gear struts. Our company had already begun experimental work on the present wing-type of radiator, but we did not feel that they had been perfected sufficiently until 1922, when they were first used on the Army racing-airplane. A large amount of the success of the Curtiss racing-airplanes can be attributed to the use of the wing-type radiator, without which the high speeds would drop between 20 and 25 m.p.h. This is also an example of the tedious and painstaking research and experimentation that must be done by the engineer in the successful development of an advanced type of equipment or construction.

In the early K-12 engines, the wet sump was used and provision was made to cool the oil through the medium of cooling pins cast into the crankcase. On the later types of engine, using a dry sump, an oil cooler was required. After a considerable amount of experimentation, a rectangular box-type was used which allowed water to pass through the cartridge radiator-tubes surrounded by the oil. The cooled water from the radiators was used to cool the oil. Owing to the high oil-pressures that were employed, this type of cooler was not entirely successful and the cylindrical type, which operates on the same principle as the rectangular-box type, was finally evolved and is being used on all D-12 and V-1400 installations.

The orthodox type of control system was used on all racing airplanes until 1923; but it was found in 1922 that the Army racing-airplane, which had a speed of more than 230 m.p.h., was difficult to control because of extreme sensitiveness. In other words, at these new high speeds, the pilot tended to overcontrol even though he moved the "stick" or the rudder but a very slight amount. As a result a geared, differential type of con-

(*Concluded on p.* 489)

Making Machine-Tools Safe

By R. F. THALNER[1]

PRODUCTION MEETING PAPER *Illustrated with* PHOTOGRAPHS

ABSTRACT

EVOLVING gradually since the time when opinion prevailed that accidents are unpreventable, modern safety methods have come into being and successfully organized effort concentrated on their application in industry has accomplished an amazingly effective system of accident prevention. In the automotive industry, effort focused on preventive measures looking toward the elimination or reduction of casualties and fatalities has resulted in greatly increased conservation of life and property; but, as new conditions and new demands continually appear, it is evident that new methods, new means and new modifications must be continually in process and that putting these forces into production requires concentrated scientific study, forethought and executive ability. Therefore, the author not only outlines previous and present practice but states the governing factors of accident-prevention progress and suggests possibilities of improvement of methods and the means for applying them, referring specifically to machine-tools.

Forethought exercised in the design of tools to make them safe as well as suited to the work is the best method, and redesign is practised when hazards become apparent after a tool is put into operation. If redesigning a tool does not make it safe to operate, the next best method is to guard it.

Among the fundamental factors governing the safe operation of tools are the following rules. Men who operate vertical drilling-machines never should wear gloves or long sleeves. Milling-cutter chips should be brushed aside only with a brush or with a stick, and holding fixtures should make it unnecessary for the workman to expose his hands unduly to the cutter. Belts and gears ought always to be covered to prevent the entanglement of workmen. Chips and long shavings from lathe tools can largely be eliminated by proper grinding of the tool, and flying particles from high-speed brass-turning operations can be controlled safely by sheet-metal guards.

Grinding-wheels and woodworking tools necessitate careful guarding, the various means, including the use of goggles, being mentioned. Hand operations and the use of shock-tools such as hammers, chisels, stamps, drills, drift-pins, punches and plugging-tools, are also discussed from the standpoint of safety. Emphasis is centered on the statements that most accidents are caused, they do not simply "happen," and that tools which cause accidents can be made safe.

SAFETY means freedom from danger and, to be free from danger, we must eliminate dangerous conditions; that is, we must prevent accidents. Safety then can be said to be accident prevention because we are keeping people free from danger by the prevention of accidents, thus making it possible for them to live their lives in safety. The prevention of accidents has become a part of business and of industrial life in America and in the older countries as well. At one time accidents were considered necessary; employers thought that accidents had to happen and employes thought that accidents were unpreventable. The public in general seemed to take it for granted that accidents are in the same class with ordinary events; but the time arrived when the idea was conceived that all accidents are not necessary. At the start, this idea was ridiculed but, by consistent effort, the few people responsible for it proved that accidents are caused and do not simply "happen." Thus, accident prevention, or the promotion of safety, one of the greatest humanitarian movements of all time, was begun.

INAUGURATION OF SAFETY CAMPAIGNS

Reviewing the past, we come to the period when railroads first adopted safety regulations and appliances. The one outstanding appliance is the airbrake because, in addition to being a wonderful safety device that has saved thousands of lives yearly, it has also revolutionized travel. It permitted trains to speed-up safely, and thus automatically brought the rural communities into closer contact with the cities. In the steel industry, many men were being crippled or killed yearly and their families were being left destitute, all because it was thought then that accidents "happened"; but the industry subscribed whole-heartedly to the safety movement in an endeavor to stop this needless waste due to accidents, and thus probably paved the way for safety measures in industry in general in this Country. Safety engineers were engaged to study the steel plants in an endeavor to eliminate the conditions that cause accidents. Machines were guarded or redesigned, plant layout was changed in some instances and many other improvements were brought about. Finally, it was proved that the prevention of accidents in industry is possible. Before long, other large industries took up this work. Included among them were many of the automobile-manufacturing plants, in which special hazards exist such as are present only where sheet-metal stamping, drop-forging, foundry work, woodworking, heat-treating, machine-shop operations and construction work are done. In turn, these companies engaged safety engineers to study their problems specifically, with the prevention of unnecessary accidents in mind. Thus was developed a great humanitarian movement; it began in a small way but was gradually enlarged until all industry of any consequence became vitally interested and made safety work a part of its organization.

In the past, accident costs were too generally supposed to be necessary overhead-costs, but time has proved that they are simply unnecessary expenses that can be curbed. One outstanding reason causing employers to learn about the high frequency and severity rates of accidents probably was that they were being continually confronted with accident expense. Although they might be interested in their employes from a humanitarian standpoint, they could not have been presented with evidence that would have been so forceful as that of the amount of money paid out each year for their accident losses. Men may be hurt, day in and day out; but, being as matter-of-fact as we are, these instances are quickly passed over and forgotten. But to have this total presented in a

[1] Safety director, Buick Motor Co., Flint, Mich.

dollar-and-cents argument immediately threw a new light upon the subject, and probably was the only way in which evidence could be accumulated to show how many lives were being lost and how many men were being crippled in the course of production, or how much material was being scrapped and how much time was lost when the process of orderly production was interrupted because of each accident. Investigation again proved that most of these accidents can be prevented; and, in many instances, the removal of the hazard and the making of the job safe speeded-up production. This brief history of accident prevention in this Country leads us to ask what has been accomplished by all this work.

Effectiveness of Safety Measures

It has been estimated conservatively that the safety movement has been responsible for the saving of 100,000 persons, or the equivalent of the population of a city of moderate size. The United States Steel Corporation has calculated that 39,374 employes were saved from serious accidents in the period from 1906 to 1923. Many other companies have shown similar decreases. The Buick Motor Co., still young in this work, has shown 1746 accidents for 1923; 726 accidents for 1924; and 287 accidents for the first 6 months of 1925. I could cite example after example, not only with respect to number of men and number of accidents but also as regards the reduction in the cost of accidents per $100 of payroll; and yet, in the face of all the safety work which has been done, it is an amazing fact that of the 85,000 lives lost in the peaceful United States because of accident last year, 23,000 of these deaths occurred in industry.

It is said that the United States is the leading nation of the world, but we are too willing to accept statements of this kind. Speaking only of fatal accidents, approximately 860 persons per 1,000,000 inhabitants are killed per year in the United States; 477, in France; 452, in Great Britain; 446, in Japan; and 225, in Denmark. Why is it that we have almost twice as many persons killed as is true of our nearest competitor? I believe that one reason is the continual "speeding-up" in America. We are trying to break all previous records on the race track, in the swimming pool and in the shop, the last being where we are trying to break production records. If we build 1000 cars today we want to build 1100 cars tomorrow and 1200 cars on the day following. I do not wish to convey the idea that I am opposed to a program of increased production on a well-planned and carefully thought-out basis, but I am opposed to the idea of spasmodic increases in production, from the safety as well as from the economic standpoints.

Fig. 1—Dangers of Drilling-Machine Operation
While Cleaning-Out a Shaving from the Back of the Fixture, the Operator's Shirt-Sleeve Caught on the Drill with the Result Shown. A Standard Rule Should Be That Workmen Shall Not Wear Gloves or Long Sleeves When Operating Machine-Tools of This Type

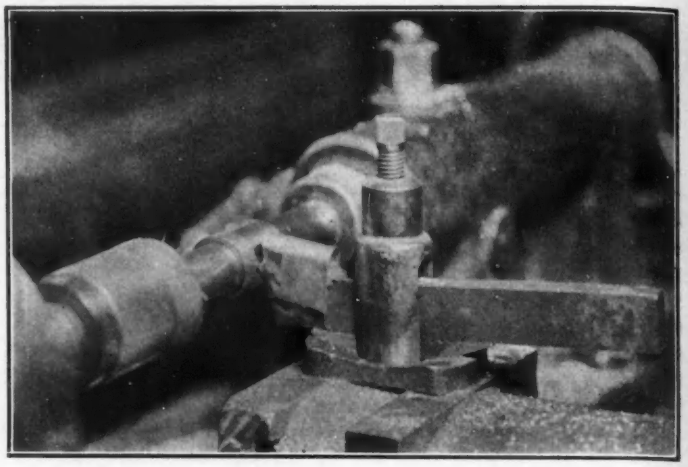

Fig. 2—Guarding of Lathe-Tools
Although Somewhat Less Dangerous than Other Machines Because the Cutting-Tool Is Stationary, Lathes Need a Sheet-Metal-Clip Chip-Guard Such As Shown To Prevent Serious Laceration of the Operator by Flying Chips and the Long Metal-Shavings That Develop When the Lathe-Tool Is Ground Improperly

We have but to contrast the business man of today with the business man of 20 years ago to sense his comparative leisure in former times and his present mad rush to get to work. It is speed, speed, wherever we turn, because the world has become a mechanical world and man-power and horsepower have gradually become almost obsolete except when used as units of measurement. We have harnessed all natural forces and are able to travel by air, sea or land because of possessing cheap and light mechanical motive-power. Thus we find that power is the cause of all this speed, and the popularity of this motive power has caused such a demand on it that our automotive industries are producing to capacity in an endeavor to speed-up production in every way possible so that more cars can be built at less expense and, consequently, sold at lower prices. So, heedless speed is directly responsible for many of our unnecessary accidents, not only on the streets but in our shops.

Safety Measures in Automotive Plants

Many types of machine, tool, jig, die and fixture exist in an automobile plant, and within each improperly designed piece of equipment lies the possibility of an accident. My paper deals specifically with only that phase of industrial safety which applies directly or indirectly to machine-tools.

In present-day production, machine-tools are many and varied and many hazards now prevalent in machine shops can be eliminated by the use of proper tools. To ask a workman to operate a machine with an unsafe tool is inviting trouble and is just as risky as giving an open razor to a baby. Sooner or later both will be injured. The best method, of course, is to apply enough forethought to the design of the tool so that it will be safe. In many instances, hazards are not apparent until a tool is put into operation; then, when they become apparent,

the tool must be redesigned. But tools have been redesigned so that they not only eliminated accidents but also increased production. If redesigning will not make a tool safe to operate, the next best thing is to guard it.

A few fundamental rules cover the safe operation of tools, and these must be adhered to by workmen; for instance, it must be standard practice for a man operating a vertical drilling-machine never to wear gloves or long sleeves. Gloves and long sleeves have injured more men than they have protected. Serious accidents occur in the manner shown in Fig. 1. In operating a milling-machine, experience has shown that the constant source of danger of injury lies in brushing the chips or shavings away from the cutter, rather than in the feed-mechanism of the machine. Consequently, the standard practice to be adhered to is to use a brush or a stick to do this work. These remedies are very simple but, in spite of the fact that workmen have been injured in this way and articles have been broadcasted telling of these injuries, some men still persist in violating these safer practices.

Belts and gears should always be covered so that it is impossible for men to be entangled in them.

Drilling machines are used extensively in automotive work and have caused many accidents. A first consider-

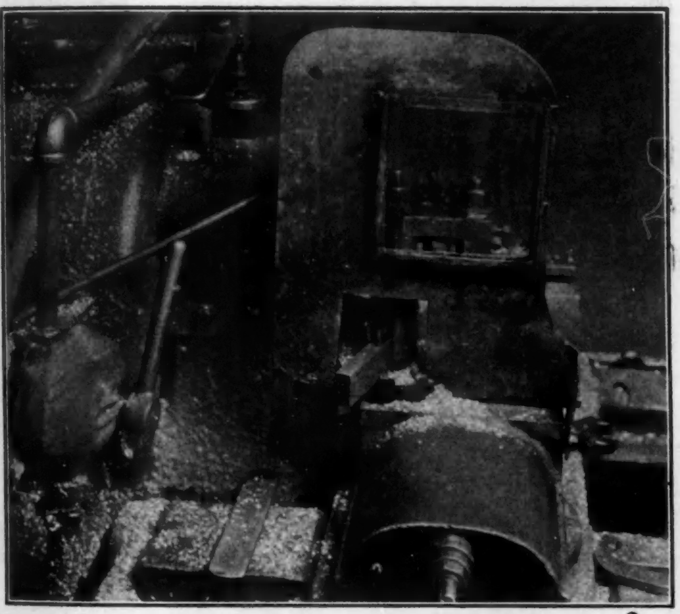

FIG. 3—CHIP-GUARDED LATHE-TOOL
In This Type of Sheet-Metal Guard, a Glass Insert Is Provided

ation is to wear no gloves or long sleeves while operating this tool. Proper grinding of the tool will eliminate the long ribbon shaving which so often causes injury to workmen, and will also cause the tool to cut more effectively. In many cases collapsible guards can be placed around the drill and, where jigs are used that are equipped with pilots, the part of the drill above the pilot can be enclosed. When it is necessary to break-up old drills to salvage the high-speed steel that has been welded to a soft shank, care should be taken to prevent flying particles.

Milling-machine cutters are very dangerous when not properly handled and operated. It is possible to cover-up these cutters in many instances, but more thought should be given toward the design of the fixture used for holding the work to make sure that the man operating the machine does not need to expose his hands unduly to the cutter.

Lathe tools probably cause fewer injuries than do the

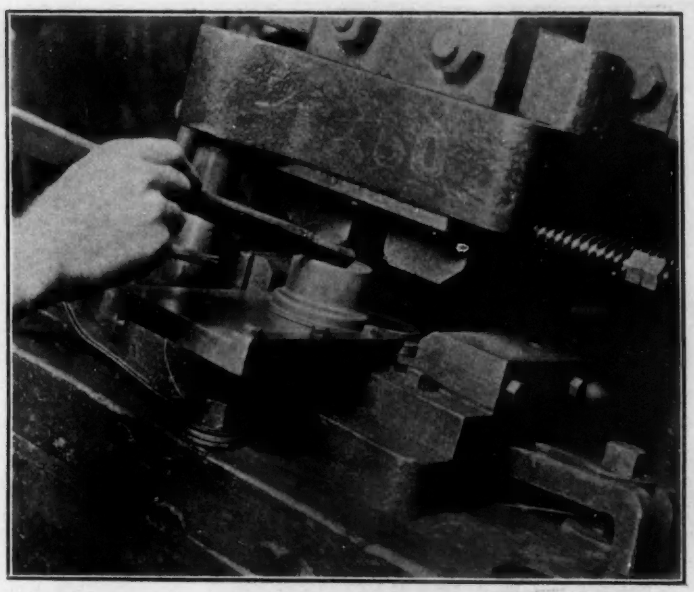

FIG. 4—SIMPLE METHOD OF FEEDING STOCK TO A PUNCH-PRESS
A Stick Is Used To Push the Stock into Position under the Punch, Thus Eliminating the Danger of Maiming the Operator's Hand

vertical drilling and the milling machine, because the cutter of a lathe is stationary; but a hazard exists that is caused by the flying chip or the long steel-shaving emanating from a piece of work that is being turned in a lathe and that flops around promiscuously. Sooner or later such a chip or shaving will cause severe lacerations and, if the workman's vitality is low, it will cause infection to develop which may result in loss of life or involve a great amount of lost time. This ribbony shaving can be eliminated by proper grinding of the tool; thus, the possibility of injury to the workmen is eliminated and a tool is produced which will cut more effectively.

Due to the high cutting-speed employed and to their brittleness, brass turnings have a tendency to fly. It is a very peculiar coincidence that flying particles in machine shops always pick for their objectives a vital spot in the human anatomy. It may be that many more particles fly which never strike the man and that the one which does strike simply completes the law of aver-

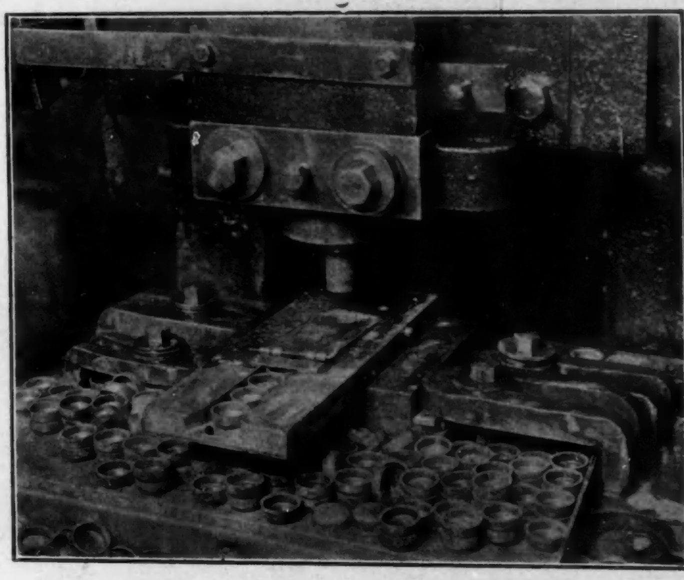

FIG. 5—A SAFELY GUARDED PUNCH-PRESS DIE
The Greatest Danger of Accident When Operating a Machine-Tool Lies at the Point of Operation. In the Case of the Punch Press, the Danger Exists at the Die. The View Shows How the Die Is Made Safe by the Use of a Metal Clip

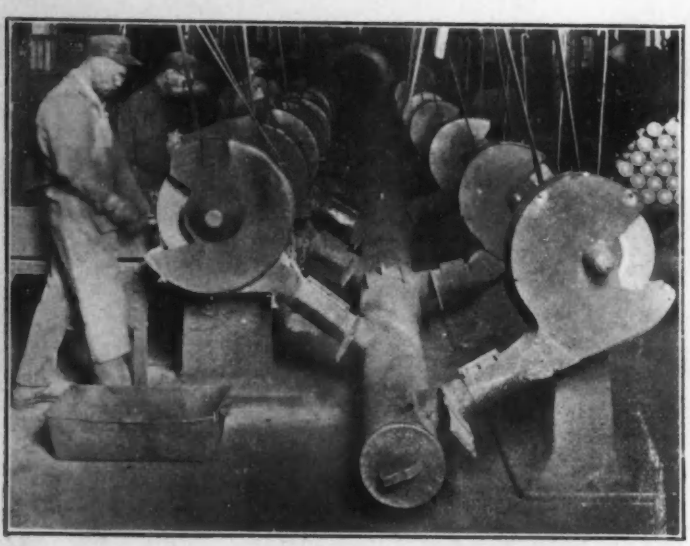

FIG. 6—SAFEGUARDING OF GRINDING OPERATIONS
Grinding Operations Formerly Were Classed Among the Most Dangerous But Have Now Been Safeguarded to the Extent Shown, in Which the Wheels Are Equipped with Guards and the Stands Are Connected with an Exhaust System That Removes the Dust and the Metal Particles. As a Basic Precaution, Extreme Care Is Used in the Manufacture of the Grinding-Wheels

ages, but many eyes are lost as a result of flying particles of metal and such accidents can be guarded against. On a brass-turning job, a very simple inexpensive guard such as that illustrated in Fig. 2 will suffice. It consists of a piece of sheet metal bent around the sides and the top of the tool near the cutting edge, and it acts as a deflector. Another sheet-metal chip-guard having a glass insert is pictured in Fig. 3.

Even after the belts and the gears on a punch press are enclosed, the punch-press die still remains the most hazardous part of the machine and one where more injury is done to human beings than by any other part of the press. The danger lies at the point of operation, or between the dies. Many devices, such as those illustrated in Figs. 4 and 5, have been put on the market in an endeavor to guard this hazardous operation. Sweep-guards, tell-tale gates and devices that harness a man's hands, have been placed on the presses and on the men in an endeavor to eliminate the possibility of an accident occurring at the point of punch-press-die operation. If a road engineer were paving a road at a sharp turn,

FIG. 7—USE OF GOGGLES TO PREVENT EYE INJURY
Although the Use of Goggles Is Avoided When Feasible, Because They Interfere with Vision and Are Uncomfortable, Their Usage Is Necessary in Some Operations. The Piece of Emery-Wheel Shown Struck the Lens That Covered the Workman's Right Eye; the Lens Was Broken But the Eye Was Not Injured

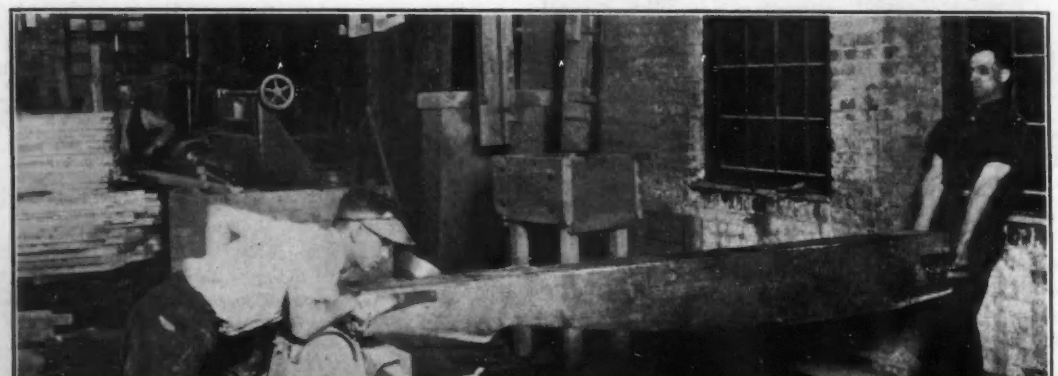

FIG. 8—DANGERS OF UNGUARDED WOODWORKING MACHINERY
The Possibilities of Serious Accident in This Dangerous Two-Man Operation on a Bull Shaping-Machine Are Apparent. It Is Guarded in the Manner Shown in Fig. 9

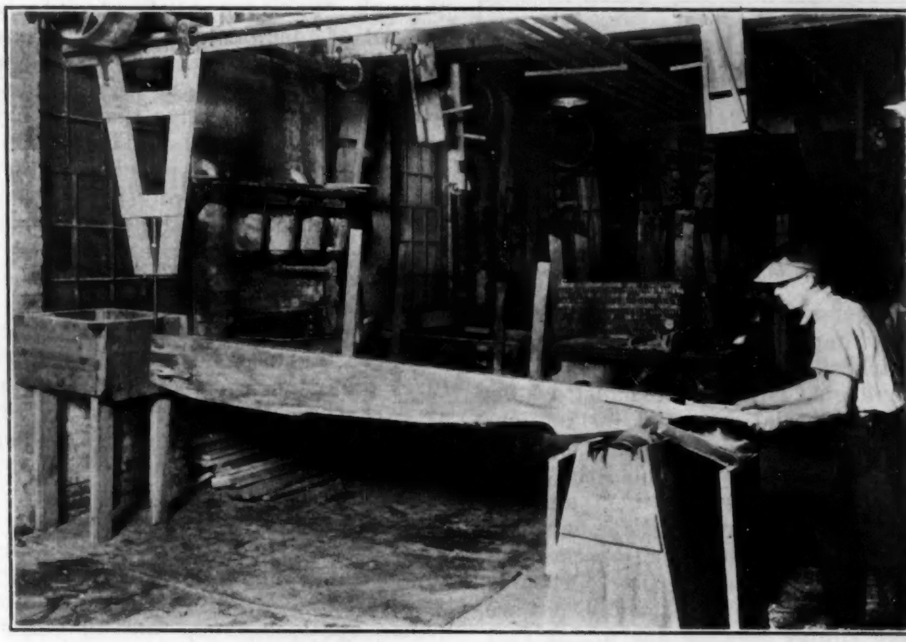

FIG. 9—METHOD OF MAKING THE OPERATION OF A BULL SHAPING-MACHINE SAFE
By Suspending the Distant End of the Stock from an Overhead Trolley and by Attaching Handles to the Near End, the Operator Can Assume Safe Positions While Working and a Second Operator Is Not Needed

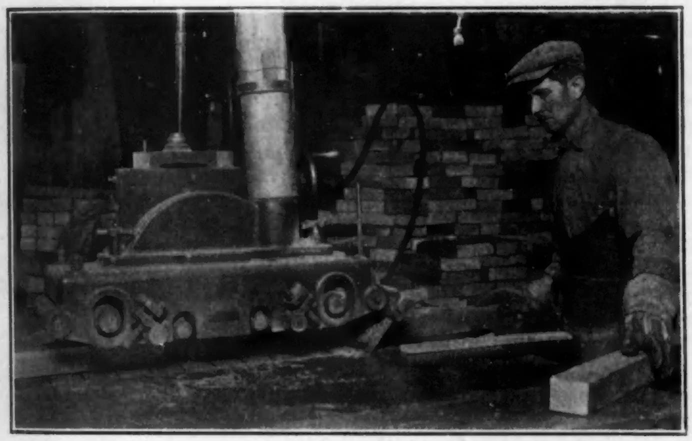

FIG. 10—SAFETY FEATURE ON A RIP-SAW MACHINE
A Dog-Guard, Properly Adjusted, Is Attached So That It Prevents the Stock from Being Kicked Back by the Saw

would it be better to build a fence around the turn to keep vehicles from running off the road or to make a curve of long radius that can be negotiated safely? The point I have in mind is that if accidents are occurring on punch-presses at the point of operation, why put on gate-guards and tell-tale devices that only cover-up the hazard temporarily? Will we not progress farther if we can remove the hazard entirely by building a safe die that not only prevents injury to the workman but speeds-up his production? If a workman knows that it is impossible for him to be hurt, he can work with less nervousness. I have known men to quit a job because they were afraid it would "get them." A man who operates a press in constant fear of the machine certainly cannot produce as much as the man whose mind is at ease in this respect; so, safe die-construction is the main problem in the press room.

GRINDING-WHEELS AND WOODWORKING TOOLS

Although a grinding-wheel may not be classed as a tool, it performs the function of cutting away material and this entitles it to discussion. Grinding-wheels have evolved from having constituted a very hazardous operation to the stage of constituting one of the safest operations in a machine shop. Great care and attention are given to the manufacture of the wheel, because it is subjected to severe strains while being operated, and the best materials and workmanship must be employed. Years ago, the breaking of an emery-wheel and the kill-

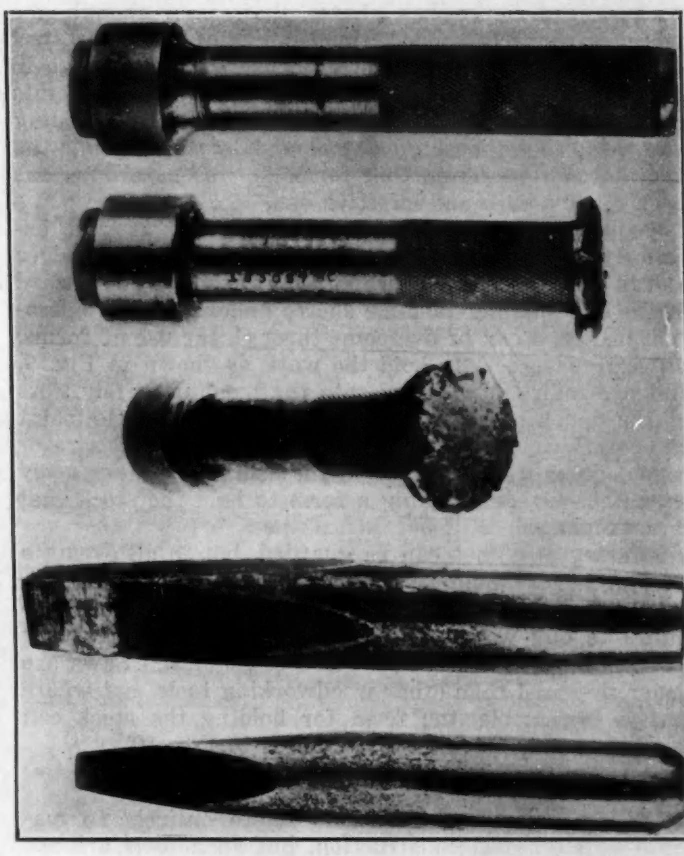

FIG. 11—MUSHROOMING EFFECT ON SHOCK-TOOLS
Various Stages of Deterioration on the Heads of Improperly Formed Shock-Tools Are Shown. The Lowest View Shows a Tool That Has a Properly Formed Head

FIG. 12—DANGERS DUE TO FLYING NAILS
Injuries Caused by Flying Nails Can Be Practically Eliminated by Using the Specially Designed "Bull's-Eye" Hammer Shown

ing or crippling for life of a man who was operating it was almost an ordinary happening. But evolution has brought the grinding-wheel to the safe stage in which it is provided with rigid guards and an exhaust system as illustrated in Fig. 6. Special care and instructions are given in regard to its mounting and the speed at which it should be run. The collars that hold the wheel have a layer of blotting paper between them and the wheel to distribute the pressure between the collars and the wheel evenly. Wheels are inspected before they are mounted to make certain that no cracks exist. Probably a great number of wheel breakages occur today, but we do not hear of damage simply because the guard that surrounds the wheel prevents any of the broken particles from flying out and striking the operator. The only time news travels is when it becomes sensational, and it is very sensational when it has to do with the killing or maiming of human beings; so the mere occurrence of having a wheel break would very likely be lost sight of in the ordinary business of today, but this is another instance that shows how safety precautions will eliminate wastes that arise from accidents.

It is a standing rule also for men who are working on heavy snagging-jobs to wear goggles for eye protection because experience has shown that, even though the wheel is properly hooded, small pieces of emery or steel are bound to fly and will often cause serious damage to men's eyes. An example of accident prevention of this character is given in Fig. 7. Thus by properly guarding and designing the original tool and by supervising the operator, an operation that formerly was hazardous has been made a safe and effective one.

Tools used in woodworking machinery are all extremely dangerous due to the very sharp cutting edges and to the high speed at which they revolve. The hazard of the bull shaping-machine shown under two-man operation in Fig. 8 can be overcome through the use of forms, properly designed, to hold the work as shown in Fig. 9, and one man can then operate the machine safely. As on the punch press, the cause of injury lies at the point of operation. If, then, we cannot make the tool safe or cannot cover it, we must keep the operator's hands away from the cutters by using a form to hold the stock that is to be shaped.

Jointing machines can be guarded, but in all events a circular head should be used in place of the old square head. The installation of round heads on jointing machines in our woodworking plant has shown that they are not only safer but also more economical. Saws are easier to guard than other woodworking tools, but where that is impossible, the form for holding the stock can be used to good advantage as shown in Fig. 10.

SHOCK-TOOLS

The foregoing considerations relate entirely to machine-tools of steel construction, but such tools are not the only ones that cause great damage to industrial employes. Many operations must be performed by hand or through the agency of shock-tools. A considerable amount of thought and scientific reasoning has been applied toward the development of machine cutting-tools, and it has resulted in the high-speed tools we have today, which are more effective than the old type due to their lasting tendencies; but shock-tools such as chisels, stamps, drills, drifts, punches and plugging-tools, have not been improved to any great extent in recent years. All are familiar with the mushrooming effect shown in Fig. 11 which takes place on shock-tools when they are put to work. The constant striking of a hammer on the top of these tools has a tendency to cause the material to work toward the outside and flare-out or "mushroom." With constant use and on account of glancing blows, fractures occur in the steel that cause uneven surfaces to appear; the succeeding blows on this slight elevation will then cause the material to be hammered out into a thin sliver that constantly works toward the circumference of the tool. A glancing blow with the hammer will then cut-off this sliver or piece of the mushroom easily and cause it to fly through the air, and it often does serious damage to the operator or to someone standing nearby. The way these slivers find their way to the human eye is uncanny and, in almost every case, they destroy the sight. In addition to being an unsafe tool a mushroomed tool is also an ineffective one, besides causing waste when the material is hammered out of the way and then broken or ground off.

Tests were made of shock-tools in one of our Buick plants. The results obtained led us to believe that the best method of dressing the tool is by using, instead of the straight chamfer, a curved edge having a radius of between one-eighth and one-quarter the diameter of the tool; three-sixteenths of the diameter was found to be very satisfactory. After being ground to such specifications, the shock-tool was found to last much longer than a tool that is straight chamfered.

Another hand-tool that, from a safety standpoint, should receive the attention of all production men is the ordinary hammer. When using a hammer on rough carpentry work and on our loading docks, we have had men lose their eyesight as a result of flying nails. Striking a glancing blow on a nail that is not set deeply enough will cause the nail to travel through the air with great force and speed. First thought suggests guarding this operation by asking the men to wear goggles, but we do not like to ask men to wear goggles if we can remove the hazard in any other way, because we know that a man cannot work as comfortably with goggles as he can without them; consequently, the tool should be made safe. At present, we are using on our loading docks a specially constructed tool known as the "bull's-eye hammer" shown in Fig. 12. It has a number of annular grooves in the hammer-face which are approximately 1/16 in. deep and about 1/16 in. wide. Since using these hammers, we have had no trouble due to the flying-nail hazard. Numerous types of corrugated-face hammer are on the market but we have found that the type having circular corrugations fulfils all requirements. Great care must be exercised in the proper hardening of these hammers, and also in making them have the proper balance. When men use hammers all day long, an improperly balanced hammer will fatigue them more quickly than one that is properly balanced. These seemingly insignificant details enter very forcefully into the argument for safety, because accidents will occur if they are omitted.

Many more instances can be cited of methods used to make machine-tools safe. The main idea is that ma-

chine-tools can be made safe either by guarding or by designing. Hand-tools likewise can be improved so that their hazards are reduced to the minimum. Bear in mind that most accidents do not simply "happen"; they are caused. Accidents cost money and cannot be absorbed in overhead charges because they constitute unnecessary *expense.* A tool that is causing accidents can be made *safe.*

THE EARTH-INDUCTION AIRPLANE COMPASS[1]

WHEN motoring, definite roads can be followed and correct directions are easily obtainable, but when flying no definite pathways exist and one cannot make inquiries. Although the airplane can travel the shortest course between two points, the course usually is not well defined by landmarks and direction-indicating instruments must be used, the most important being the compass.

As ordinarily used on the ground, a magnetic compass is an accurate instrument; but such a compass mounted on a vibrating board located within a few feet of several hundred pounds of iron and subjected to rapid accelerations would give indications of little value. An airplane compass must be visible to the pilot; that is, mounted in front of him. But here it is influenced by the engine, by current-bearing wires and machine guns in front, and perhaps by several thousand pounds of bombs in steel shells beneath or behind it. To have the compass card level, its mass must be unbalanced to counteract the tendency of the north-seeking ends of the magnet to point downward; but this subjects the instrument to error due to acceleration caused by airplane vibrations, oscillations and turns. A magnetic compass also requires a certain time to assume the correct reading after a turn of the airplane has been made, because of its oscillation period. In spite of these difficulties, the magnetic compass would give fairly reliable indications when flying straight and level were it not for the fact that the magnetic disturbance due to the presence of the large mass of iron is continually changing because of the effect of vibration and the change in the effect of the earth's field on different headings. If it were possible to place the compass where disturbances due to the earth's magnetic field were small, good results could be obtained; but, in such a position, it would not be visible to the pilot.

Distance Reading of a Compass

Optical systems for reading a compass from a distant location have been tried, but they were found to be impracticable. A distant-reading magnetic-compass that employs a selenium cell as a means of transmitting the compass indication to a distance was built by Carl Hamberg, of Germany, but tests did not give satisfactory results. Work on the development of a distant-reading compass was begun in 1920 by the Bureau of Standards, funds being apportioned by the engineering division of the Air Service, and the first satisfactory working model of an induction type of compass was completed and tested in 1921. In spite of the great amount of development work already done on the induction type of compass, much remains to be done; but present models are greatly superior to the magnetic compass in all respects except that of durability.

The Induction Compass

In a magnetic compass a magnet is allowed to align itself with the magnetic lines of force of the earth, but in an induction compass a current is generated by rotating coils of wire in the earth's magnetic field and the direction of the field is determined by the amount of current generated at any instant in the various coils. To date, two types of induction compass have been developed, a single-circuit and a two-circuit type.

In the single-circuit type, a drum-wound armature equipped with a commutator similar to that used in a direct-current generator is rotated in the earth's field. This coil is placed where the magnetic disturbance is minimum and is rotated by a small propeller inserted in the airstream. The current generated is carried to a small galvanometer placed in front of the pilot. The brushes are then rotated so that they are in contact through the commutator with a coil of wire in which no current is being generated and, from the position of the brushes, the direction of the earth's lines of force can be determined. The position of the brushes with reference to the axis of the aircraft will then give the direction in which the aircraft is heading.

In practice, the brushes are rotated by a controller placed on the instrument board, by a rod connected to the generator. The controller is marked so that, when it is set to have no deflection of the galvanometer pointer, the course on which the aircraft is headed can be read directly. If the aircraft is turned to the right, current will flow through the galvanometer and the pointer will move to the right; for turns to the left, the current generated will be in the opposite direction and the pointer will move to the left.

In the two-circuit type of induction compass two sets of stationary brushes are placed 90 deg. apart. The current from the four brushes is carried to the four corners of a Wheatstone bridge placed on the instrument board. By means of a rotating arm that makes contact with the bridge, current can be carried from any two opposite points to a galvanometer. The arm is rotated until no current is flowing through the galvanometer, and the heading of the aircraft can be read directly from a dial. The generator is hung in a manner similar to that of a pendulum, and the gyroscopic action of the rotating armature tends to stabilize it so that its axis remains vertical during slight oscillations of the aircraft.

Induction-Compass Advantages

The induction compass has many advantages over the magnetic type of compass. It has an accuracy of 1.5 deg., compared with the 5-deg. limit of accuracy of the present airplane magnetic compass. In many airplanes, it is impossible to place a magnetic compass so that it will give readings that are even approximately correct. Since it can be read at a distant point, an induction compass can be placed where it is undisturbed by local magnetic fields. The magnetic compass is affected by vibration and, once disturbed, requires considerable time for stabilization, but vibration does not affect an induction compass and it instantly shows the course on which an aircraft is headed. The induction compass is more easily read than is the magnetic compass, since it is necessary only to keep the pointer of the induction-compass indicator on zero to maintain the correct airplane-course. By the use of suitable relays, it is possible to use the induction compass to operate mechanical devices. A recording induction compass already has been made and tested by the engineering division of the Air Service in which the energy from the generator was magnified by a relay to operate a pen moving on a rotating drum and an actual record of the course flown was obtained. By further development along this same line, it should be possible to make the induction compass steer an airplane automatically on any desired course.

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[1] Abstract of an address made by George P. Luckey at McCook Field, Dayton, Ohio, to representatives of the American Society of Mechanical Engineers and members of the Dayton Section. Mr. Luckey is chief of the instrument branch, engineering division, Air Service.

Operation of the Air Mail Service

By J. E. WHITBECK[1]

AERONAUTIC MEETING PAPER

ABSTRACT

THE personnel and the ground facilities that have produced such excellent results in the Air Mail Service are discussed apart from the flying equipment and its operation in the air. An airway is on the ground and the performance and safety of the pilots are dependent upon the ground facilities provided and the efficiency of the ground personnel. Pilots perform a highly important part in the operation of airlines and no matter how good the flying equipment may be, the desired results cannot be obtained without thoroughly trained and capable pilots. When selecting new pilots, the Air Mail Service looks for men who handle an airplane in a businesslike way and who are able, without taking unnecessary risks, to fly the ship without letting the ship fly them. Desired qualifications are that an applicant should have had 400 hr. in the air, of which 200 hr. shall have been behind a Liberty engine or one of equal size; have learned to fly before he was 25 years of age; have a knowledge of navigation; be able to fly a given course cross-country; and be in good physical condition and especially have good eyesight. The Air Mail Service believes that it has the best group of pilots in the world. For a period of 2 years it did not take on, discharge or lose a pilot. An ample supply of pilots is available for the next 5 years at least, as 10,000 pilots were trained during the late war.

Maintenance of the flying equipment is the most important and most difficult part of the work. Morale of the pilots can very easily be ruined by giving them airplanes to fly which are not in good condition. A thoroughly organized force of trained mechanics, working under careful supervision, is needed. A typical terminal-field organization consists of 13 men reporting directly to the field manager and 18 reporting to the field manager through the chief mechanic. The organization includes chief mechanics and crew chiefs, engine and airplane mechanics, field and stock clerks, radio operators, a chauffeur, an automobile mechanic, riggers and mechanics, helpers, electricians, an instrument man and a parachute maintenance man.

The system of inspection after every trip and of reporting on the condition of the engine and airplane is described in detail. The inspections are checked and double-checked before being O. K'd by the chief mechanic and the airplane turned over again to a pilot. Engines are overhauled after every 100 hr. of flying and after five or six overhauls are torn down and about 30 per cent of the parts-value is salvaged, the usable parts being used in building-up other engines. Mechanical difficulties cause forced landings once in each 400 hr. of flying. Thirty per cent of the troubles are with the cooling system, 29 per cent with ignition, 11 per cent with carburetion and 8 per cent with lubrication. The airplanes average about 800 hr. of flying before they are given a major overhaul and rebuilding. The fabric covering is renewed after about 500 hr. Only one airplane failure has occurred in the last 5 years.

Terminal, semi-terminal and emergency landing-fields and their equipment are described. Reports of weather conditions and of arrivals and departures of airplanes are transmitted by radio except when static interferes and then the long-distance telephone is used. It may be that some day the Air Mail Service will have its own telephone or telegraph lines along its airways, as the railroads do, and the same pole-lines may carry current for the beacon lights. It has been said that the Air Mail has the best-lighted airway in the world, but it has been lighted only a little more than 1 year and the officials can see wherein great improvements are possible. An airway can be so prepared and lighted as positively to insure as safe and regular operation as exists in any method of transportation and at a cost of only about 10 per cent of the cost of building a single-track railroad.

AT the present time we are operating the transcontinental service daily in both directions between New York City and San Francisco. Since July 1, we have also been operating an overnight service between New York City and Chicago, in both directions, nightly excepting Saturdays, Sundays and legal holidays. The night service, on a prearranged schedule, between New York City and Chicago is probably the most difficult undertaking that has ever been attempted in aeronautics. There are 300 miles of mountainous and thickly timbered country in Pennsylvania, with weather conditions that change more rapidly than in any other section of the United States. Our records also show that the average altitude of clouds is lower over Pennsylvania and eastern Ohio than on any section of the transcontinental route. Perhaps the Delaware, Susquehanna and Allegheny watersheds have some influence on these unusual conditions. Then night fogs occur along the coast, across Pennsylvania and around Cleveland and Chicago in the Great Lakes region. About 50 per cent of our night flying is done above low clouds or fog and out of sight of the ground.

DIVISION SUPERVISORY ORGANIZATION

Our service is divided into four operating divisions; Western, Mountain, Central and Eastern. We have a repair-base and warehouse at Chicago, where the major overhaul of both airplanes and engines for all operating divisions is made. The warehouse carries a complete stock of airplane and engine parts, from which all operating fields obtain most of their supplies. All division superintendents and the superintendent of the repair-base and warehouse report to the general superintendent, who reports direct to the Second Assistant Postmaster General.

A division-office organization consists of the division superintendent, the assistant division superintendent and the division clerk, with one or two assistants. It handles all reports and paper work from the various operating fields on the division and makes reports of all activities on the division to the general superintendent's office. The division office makes up all airplane and pilot schedules, and all general instructions to pilots, which are transmitted through the various field managers. That is the general layout of the supervisory organization.

Assuming that our operation and maintenance problems will be of most interest, I will endeavor to outline the things we consider most important to reasonably safe and regular operation. They may be classified under

[1] Superintendent, eastern division of the Air Mail Service, Cleveland.

the headings, (*a*) flying personnel, (*b*) flying equipment, (*c*) ground personnel and (*d*) airways and airports.

Qualifications of the Flying Personnel

Pilots perform a very important part in the operation of airlines. No matter how good the flying equipment may be, the desired results cannot be obtained without thoroughly trained capable pilots. In selecting new pilots, the Air Mail Service looks for the pilot who handles his airplane in a businesslike way. Without taking any unnecessary chances, he must be able to fly his ship and not let the ship fly him. A pilot, to qualify, should have had 400 hr. in the air. Two hundred should have been back of a Liberty engine or one of similar size. At least 100 hr. should have been in cross-country flying. We find at least two kinds of pilot; cross-country and field. About 10 per cent of the pilots who are tried out for the service fail in their tests on account of their inability to fly a given course cross-country.

A college education is desirable. We find that the highly developed mind is less likely to make mistakes when quick decisions are required. A knowledge of navigation is also desirable. A pilot should be in average good physical condition; good eyesight is the most important physical qualification.

It is desirable that pilots should have learned to fly before they were 25 years of age. The young mind seems to acquire and retain longer the finer points of flying, just as a young man can learn how to drive a car much more quickly than an older person. The "good flying-life" of a pilot has not been definitely determined; however, the following rule will apply to the average case: If a man learns to fly before he is 25 years of age, he may expect 20 years of "good flying-life." If he learns to fly after he is 25 years of age, multiply the difference between his age and 25 by 2 and subtract from 20. The rule was made up from the records of 87 pilots over a period of 10 years and is meant to apply only to the professional pilot.

Pilots Must Know Their Runs

We consider it just as essential for a pilot to know his run as it is for a railroad engineer to know the curves, switches, cross-overs, signals, yards and stops on his division. Before a pilot flies mail, he must be familiar with every emergency field and beacon light and with weather signals, mountain ranges and their height above sea level and the local weather conditions along the course.

Pilots' runs average about 400 miles in length, with a service stop at the middle of the run, or about every 200 miles. We find that pilots can fly 4 hr. per day and 3 or 4 days per week without any indication of going stale.

The employment turnover of pilots is very low. Recently for a period of nearly 2 years we did not hire, discharge or lose a pilot for any cause. Forty-three pilots were on the payroll and more than 3,000,000 miles of flying was done in that period. The Air Mail pilots are well satisfied with their positions. Most of them are married men with families. Those on both day and night schedule earn between $5,000 and $6,000 per year.

We have applications from many pilots who wish to obtain positions with the service and the indications are that the pilot supply is ample for several years to come, probably 5 years at least. About 10,000 pilots were trained during the late war.

It may be of interest to know that 84 per cent of the pilots on the Eastern Division are college graduates. Two of them have been flying for 15 years, with no indication of their going stale. Eighty-five per cent have had more than 3000 hr. in the air in the Air Mail Service. We think we have the best group of pilots in the world, because the only way to develop a thoroughly capable professional pilot is by flying a regular schedule both day and night, winter and summer, and almost regardless of weather conditions.

Maintenance of the Flying Equipment

It is just as important to have airplanes and engines in good condition as it is to have good pilots to fly them, because the morale of pilots can be ruined very easily by giving them airplanes to fly which are not in proper condition. The efficient maintenance of airplanes and engines is, therefore, most difficult as well as most important work. It involves a considerable amount of detailed work by thoroughly trained mechanics, with very careful supervision and inspection.

Airplanes and pilots are changed about every 400 miles in very much the same way that railroads change engines and engineers, but certain airplanes and pilots are kept on their own runs. When an airplane arrives at the end of its run, it is received by a crew, composed of the crew chief, who is both an expert airplane and engine mechanic; an expert airplane mechanic, or rigger, and an expert engine mechanic and a mechanic's helper. They all first assist in transferring the cargo to the departing airplane, then the engine mechanic proceeds to check every detail of the powerplant and its functioning. At the same time, the rigger is checking every detail of the airplane, the helper services it with fuel, oil and water under the direction of the crew chief and the quantities taken are very carefully checked against the flying time.

In the meantime, the pilot has made out a report-card concerning the flying qualities of the airplane and the functioning of the engine. This card is passed along to the crew chief, who, with his crew, makes the necessary adjustments. Then the powerplant is "run up" and if everything checks out all right, any changes that have been made are noted on the card and it is O.K'd by the crew chief and attached to the airplane.

A complete record of the engine is kept in the engine logbook, which is always carried in the airplane and is a history of the engine and its functioning as long as it is in existence. Entries are made by the crew chief.

After the crew chief's O.K., the ship is gone over by an inspector and, when O.K'd by him, it is put in its assigned place in the hangar until 2 hr. before its next scheduled trip, when it is brought out and completely checked again by another crew. It must also be O.K'd by the chief mechanic before it is turned over to the pilot. It may be that some of this checking and double-checking can be eliminated with the improved types of airplanes and engines that are being produced at this time.

Engine Overhauls and Engine Life

Engines are overhauled after every 100 hr. of flying. The first overhaul is classed as a "top" overhaul and is made by the operating field-force. Subsequent overhauls are made at the repair-base. Engines are overhauled five or six times, after which they lose their identity. However, probably 30 per cent of their parts-value is salvaged and the parts are used in building-up other engines. We have some crankshafts and crankcases that have been run more than 1000 hr. and destruction tests indicate that they are just as safe to run as new ones.

Our records for the last year indicate that we have

mechanical difficulties that cause forced landings once in each 400 hr. of flying. Thirty per cent of these mechanical difficulties are with the cooling system, 29 per cent with ignition, 11 per cent with carburetion and 8 per cent with lubrication. The rest are miscellaneous failures of valves, valve-springs, rocker-arms, cylinder jackets, and the like.

The Air Mail planes average about 800 hr. of flying before they are given a major overhaul and rebuilding; this includes airplanes damaged in accidents. After about 500 hr., the fabric covering is renewed by the field operating-force and the airplane is given a very thorough inspection, any parts that show any sign of deterioration being replaced. We have had only one airplane failure in the last 5 years. That was the failure of a control-stick at the place where the steel tube was welded to the U-shaped fitting at its base.

As regards spare airplanes, we have one ship on the ground for every ship in the air and a spare engine available for every ship in the air daily. The stock of spare parts carried at the operating fields is very small, as most of our spare parts are assembled in complete flying units, which are always tuned-up and ready to go.

Composition of the Ground Personnel

Ground personnel plays the most important part in the operation of airplanes. A thoroughly organized force of trained mechanics under careful supervision is needed to obtain the desired results. A typical terminal-field organization for the handling of four ships per day is as follows:

Reporting Direct to Field Manager	
Chief mechanics	2
Inspectors	2
Field clerks	2
Stock clerks	2
Chauffeur	1
Automobile mechanic	1
Radio operators	3
Reporting to Field Manager through Chief Mechanic	
Crew chiefs	2
Mechanics, engine	4
Mechanics, riggers	4
Mechanics, helpers	4
Electricians	2
Instrument man	1
Parachute maintenance man	1

This is the force at a terminal-field such as that in Cleveland, where four ships in and four ships out are handled on the day-and-night schedule.

Chief mechanics, crew chiefs and inspectors should be expert mechanics on both airplanes and engines. Engine mechanics and riggers should have 3 years' experience. The supply of good airplane and engine mechanics is not keeping up with the demand. We have found it necessary to begin training men in the last year. It seems likely that future activities will have to train a considerable part of their mechanical forces and it must not be expected that the training of a mechanical force and whipping it into a smoothly working organization can be done overnight. An attempt to do this in the early days of our service was almost fatal, for, after all is said, an airway is on the ground and the performance and safety of the pilots are limited by the efficiency of the ground personnel and the ground facilities provided.

Equipment of Airways and Airports

A typical terminal-field comprises not less than 120 acres and has runways 2400 ft. long in two directions. From the operating viewpoint, it is desirable to have terminal-fields located some distance from large industrial centers because of the smoke and haze that usually hang over such centers. This is especially true if night-flying operations are contemplated. The Air Mail Service has found that it can carry on night operations under moderately bad fog conditions when smoke and haze are not mixed with the fog.

The terminal-field equipment at Hadley Field, New Jersey, consists of two hangars 85 x 100 ft., with 14-ft. clear headroom, concrete floors and walls, wood-truss roofs and doors at both ends. One side-wall is of glass in steel sash; on the opposite side is a lean-to 20 x 100 ft., with 10-ft. headroom, which contains offices, shops, stockroom, garages and so on. Hangar floors have a 6-in. slope from the middle of the hangar toward the doors at either end. This allows airplanes to be run out of the hangar readily by one man.

All buildings are flood-lighted, signboard style, to give daylight perspective. A 500,000,000-cp. flood-light is provided for field lighting. The field is outlined with 60-cp. 6.6-volt boundary lights connected on a street-lighting series-circuit with constant-current transformer. Steel-taped cable is placed under ground to supply the current. An illuminated wind-direction cone is mounted on top of one of the hangars, as is also a 24-in. revolving beacon that guides the pilot to the field. These beacons use a 1000-watt lamp and revolve six times per min. The beam is raised 1½ deg. above the horizon. Between New York City and Chicago 70 of these beacons are used.

Accurate weather information is essential for night operations. Thermometers, barometers and anemometers are provided at each terminal-field to assist in judging meteorological conditions; a beacon throwing a sharp beam of light upward at a 45-deg. angle is provided to determine the height of clouds at night; field managers, chief mechanics, inspectors and crew chiefs are trained to make meteorological observations.

Each terminal-field has a radio telegraph station and uses it to report weather conditions, departures and arrivals of airplanes, and to give other information to the different terminal-fields and the division office. The radio service is excellent when it works, but when bad storms occur they are usually accompanied by bad static conditions, at which times we use the long-distance telephone. It may be that some day we shall handle our communications as the railroads do, by having a telephone or telegraph wire along the course. The same pole-line might carry current for the beacon lights as they were desired.

No machine-shop equipment is located at any of the operating fields. Bench and hand-tools are provided to the extent of about $450 worth.

Emergency-Field Layout and Equipment

A typical emergency field is comprised of about 45 acres and is about 2000 ft. long and from 800 to 1000 ft. wide, the long way being east and west on account of the prevailing winds in the eastern section of the Country. The east and west approaches should be clear, the surface should be solid and it should have the necessary drainage to make landings safe in the wet seasons.

The equipment on an emergency field consists of a 24-in. revolving beacon, mounted on a 50-ft. steel windmill tower. Current is supplied by a 1500-watt farm lighting-plant. A shack 12 ft. square houses the lighting plant and a telephone. A caretaker is employed and is on duty daily from sundown until sunrise. The emergency fields are outlined with primary-battery boundary

lights placed about 300 ft. apart. An illuminated wind-direction cone is mounted on the beacon tower.

Fifty emergency fields are located between New York City and Chicago, 36 of which are between New York City and Cleveland, located an average of 13 miles apart across the mountainous and timbered country. Between Cleveland and Chicago, where the country is fairly flat and clear, they are 25 miles apart. It is believed that, with the number of emergency fields we now have on the Eastern Division, the hazard has been removed from about 95 per cent of the forced landings that may occur on account of mechanical difficulties or bad weather.

Every 100 miles along the airway we have selected what we call a semi-terminal field. It comprises from 70 to 80 acres, and is a four-way field. Here is carried a stock of gasoline and oil for airplanes that may land and also a small stock of repair-parts that may be needed. These fields are equipped with long-distance telephone service and a semaphore arrangement of red, white and green electric lights that are used to signal to the passing pilot what the weather conditions are for the next 100 miles ahead.

Safe Airways Possible at Low Cost

I have heard it stated that the Air Mail Service has the best-lighted airway in the world. That may be true, yet it has been lighted only a little more than a year, certain parts of it only a few months, and we can see already wherein vast improvement is possible. I am firmly convinced that an airway can be so prepared and lighted as positively to insure as safe and regular operation as exists in any method of transportation today, and, although providing transportation at more than twice the speed of passenger trains, the cost would be only about 10 per cent of what it costs to build a single-track railroad.

I have purposely refrained from making any detailed statements regarding the cost of operating the service, because, for one reason, accurate detailed statements were not readily available on short notice. However, a total of less than $10,000,000 has been appropriated for the Air Mail Service since its inception in the spring of 1918. In that time the airplanes have flown more than 10,000,000 miles. We have about $3,000,000 worth of buildings, materials and equipment. A large sum of money has been returned to the Government in postage, as it is estimated by good authority that the service has carried more than 26,000,000 letters. We have about 500 thoroughly trained pilots and mechanics, who are accustomed to work on schedule regardless of weather conditions. Their value as an adjunct to the military service can be estimated by anyone for himself.

EVOLUTION OF A MODERN RACING AIRPLANE

(*Concluded from p.* 478)

trol for rudder and elevator was evolved and was used on the 1923 Navy racing-airplane. With this type of control, it is possible to move the stick a considerable amount and yet to produce only a very small movement of the elevator. At large displacements of the stick, the elevator responds more quickly and moves relatively faster. As a result, the 1923 racing airplanes were much easier to fly than were any of the machines that were flown in the previous races.

Final Tests and Results

After the first unit of a contract is completed, it is carefully sand tested to make doubly sure that no defects exist and that it will bear up under the gruelling flights and maneuvers to which it will be subjected. The 1925 model was static tested to simulate high speed, low speed, inverted flight, two-point landing with a side-wind and tail-skid landing. In addition, all control surfaces and control systems were tested to load capacity. Only a few very minor changes were incorporated in the finished product as a result of the findings of these tests. Without doubt, they are the strongest airplanes ever constructed for either the Army or the Navy.

The introduction of each year's new type is a development process that concerns each previous airplane as much as it does the airplane in hand. The outline covers a period of 5 or 6 years of development that has been gradual, rather than the period of 6 months that is needed to produce a new design. When this outline was written, the 1925 racing airplanes had passed and had exceeded the requirements of their acceptance tests and were being flown by the Army and the Navy pilots in their practice flights. Our guaranteed speed had been exceeded by almost 10 m.p.h. During the period of these tests we read daily accounts of the wonderful speeds of these racing airplanes and of the skill and daring of the pilots who operated them, but very little about the corps of engineers who were responsible for their design and construction. To progress year by year in the design and the construction of airplanes requires a skilled staff of engineers who have not only the necessary creative ability to conceive new ideas but who have the ability to make use of and to improve former ideas. Their reward lies in the knowledge that the product is complete and that, during its tests, it exceeded all the requirements of the contract.

Prevention of Shimmy by Hydraulic Steering-Control

By J. W. WHITE[1]

BUFFALO SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

ABSTRACT

EXPERIMENTS with hydraulic steering-control with the object of preventing or reducing shimmying and tramping were made by the author, who asserts that the elimination of backlash by doing away with mechanical joints and by holding the front wheels as rigid as the rear wheels has been amply proved by the results to be a long step in the right direction. With a Marmon car fitted with an hydraulic steering-system and driven over the roughest roads it was impossible to discern any front-wheel wabble as the car approached and passed the observer. The car could be driven unbelievable distances with the hands removed from the steering-wheel and driven over curbs without manual control; the tendency to tramp was greatly diminished, the radiator vibration was noticeably reduced, the sense of stability of the front end of the car was comparable with that at the rear end, the front wheels would straighten out of a turn with the slightest pressure on the steering-wheel, and no vibration of the hand-wheel due to road roughness was noticed.

Six differences between the front and the rear ends of a car that may be responsible for shimmying and tramping are listed and analyzed briefly, the most important being the 8 or 10 mechanical joints between the front wheels and the steering-wheel. Based on this analysis, it is asserted that if the front wheels can be held rigid the problems will be solved. This is accomplished by the hydraulic system, which acts as a dashpot between the wheels and the axle and dispenses with mechanical joints that have a certain amount of elasticity, which permits of the development of backlash and increases with use.

Means by which hydraulic steering is effected are described briefly, since they are experimental and it is probable that better means will be developed. The major elements are a sliding cylinder working transversely on a stationary piston clamped by the piston-rods to the front axle; a divided cross tie-rod secured at the inner ends to the movable cylinder and at the outer ends to the steering-knuckle arms; flexible tubes from the ends of the hollow piston-rods to rigid tubes on the car frame that connect with an oil-pump at the foot of the steering-column, and an oil supply-tank on the dash, with a check-valve below, from which the system is automatically kept full. The geometry of the steering action with the divided cross tie-rod is much nearer theoretically correct than that with the customary single tie-rod.

IN considering the possibilities of hydraulic steering-control, the prevention or the reduction of shimmy is of foremost importance. Many reasons for shimmying have been advanced and as many preventive measures suggested. A means that will remedy the fault in one car often has no effect in another car; in fact, it may be stated broadly that very little uniformity in results has been obtained. It is even claimed that in a great many cars that do not shimmy it "just happens so," while many others that do shimmy continue to do so in spite of exhaustive research and experiments.

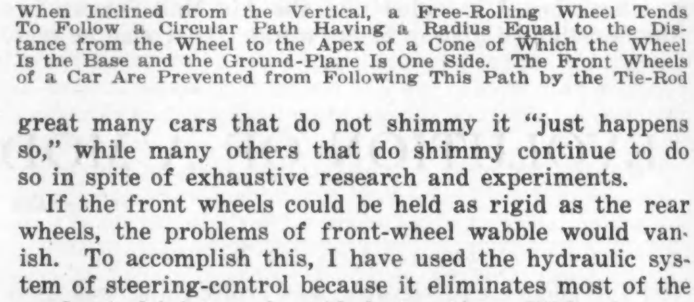

FIG. 1—CAMBER OF FRONT WHEELS

When Inclined from the Vertical, a Free-Rolling Wheel Tends To Follow a Circular Path Having a Radius Equal to the Distance from the Wheel to the Apex of a Cone of Which the Wheel Is the Base and the Ground-Plane Is One Side. The Front Wheels of a Car Are Prevented from Following This Path by the Tie-Rod

If the front wheels could be held as rigid as the rear wheels, the problems of front-wheel wabble would vanish. To accomplish this, I have used the hydraulic system of steering-control because it eliminates most of the mechanical joints and avoids lost motion. While the system is partially reversible, like the usual mechanical steering-gear, the non-reversible effect is damped or checked by the dashpot action of the liquid in the connecting pipes and the "steering-wheel fight," as it is termed, is avoided. The wheels do not turn except under the action of the driver on the steering-wheel because they are held rigidly and the drag-link action is removed.

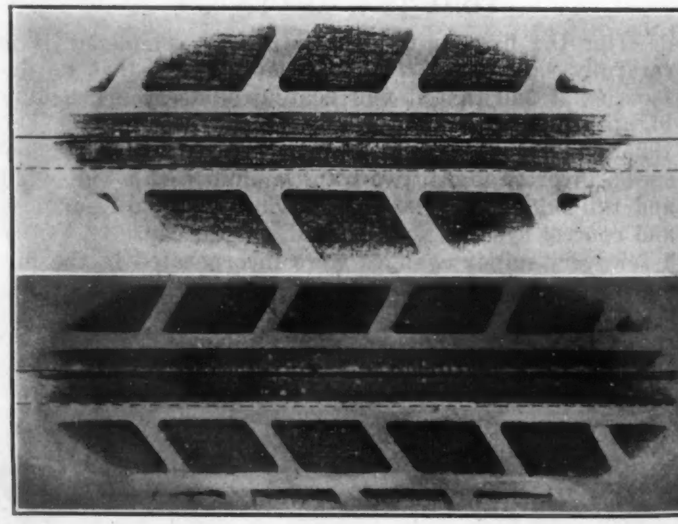

FIG. 2—CURVED FOOTPRINTS OF FRONT TIRES

Owing to the Inclination of the Wheels, the Tires Tend To Run in a Circle. This, in Itself, Is Sufficient To Produce Shimmying. The Upper Print Is That of a 4½-In. High-Pressure Tire, and the Lower Print Is That of a 6.77-In. Low-Pressure Tire, with a Car Weight of 2850 Lb. The Straight Lines through the Centers of the Treads Show the Amount of Curvature

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When a Marmon car fitted with an experimental hydraulic steering-system was driven over the roughest roads it was impossible to discern any front-wheel wabble as the car approached and passed the observer. It could be driven unbelievable distances with the hands removed from the steering-wheel. The car could be driven over curbs without manual control and the marks of the off-side tires would show no deviation from a true rolling course. The tendency to "tramp" was greatly reduced, the radiator vibration was noticeably diminished, the sense of stability at the front end of the car was comparable with that at the rear end, and no vibration from the road was felt at the handwheel, yet the front wheels would straighten out of a turn with the slightest pressure on the steering-wheel.

Front and Rear End Differences That Cause Shimmying

It is conceded generally that the rear wheels of a car do not shimmy. This being the case, wherein lie the differences between the front and the rear wheels? They are worth setting forth so that we may take a new inventory of them. The difference in spring-suspension is not sufficient to record but the following differences are important:

(1) The engine torque is directly above the front axle and gives the frame a positive reaction in one direction proportionate to torque, irrespective of road conditions. Its action may be likened to the bouncing of a rubber ball with a rubber attached to ensure its return. This effect is amplified when balloon tires are used and I believe it is a factor in producing shimmy. I think it also stimulates tramping. Stiffening the end of the frame will often reduce both tramping and shimmying, so I think it is safe to list this as a difference in comparison with the rear end

(2) The front wheels lean outward and are also toed-inward, so that they tend to run in a straight path. The natural path of a leaning wheel when rolling free is a circle having a radius equal to the distance from the base to the apex of a cone of which the wheel is the base and the ground plane forms one side, as in Fig. 1. The angle of the wheel with the road surface produces a tire footprint that is curved, as in Fig. 2, in which the upper photograph shows the print of a high-pressure tire and the lower photograph that of a low-pressure tire. This effect is sufficient, in itself, to produce shimmying

(3) The front axle is provided with king-pins so that the wheels may be turned from a true path and by reason of their design a certain amount of elasticity is present in the steering-arms and other connected parts. The cross tie-rod is under compression and as the tractive resistance of one wheel varies with relation to that of the opposite wheel, a sinuous movement of the wheels occurs

(4) The inclination of the king-pins or rake of the front axle causes an actual rise or fall of the front end of the car when the front wheels are turned at an angle to the frame

(5) The drag-link that controls the steering mechanism is located positively on the frame, whereas the axle and its steering-arms shift backward and forward with the spring deflections. Moreover, the vertical travel of the forward end of the conventional drag-link is through an arc opposite to that of the spring travel, so the above difference is exaggerated.

(6) The most important difference is the 8 or 10 mechanical joints between the front wheels and the steering-wheel, which allow all of the influences mentioned to amplify by reason of the backlash in the mechanism, which not only cannot be eliminated but constantly increases. It is possible to reduce all of these actions scientifically and means for doing so have been applied with some measure of success. The aim is to hold the front wheels rigidly, which brings us

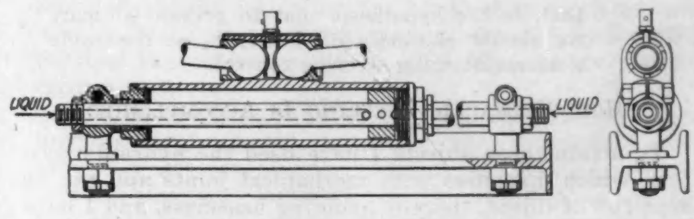

Fig. 4—Details of Axle Cylinder
The Drawing Shows How the Piston-Rods Are Secured to the Front Axle and to the Piston and Also the Ball-and-Socket Attachment of the Divided Tie-Rod to the Movable Cylinder

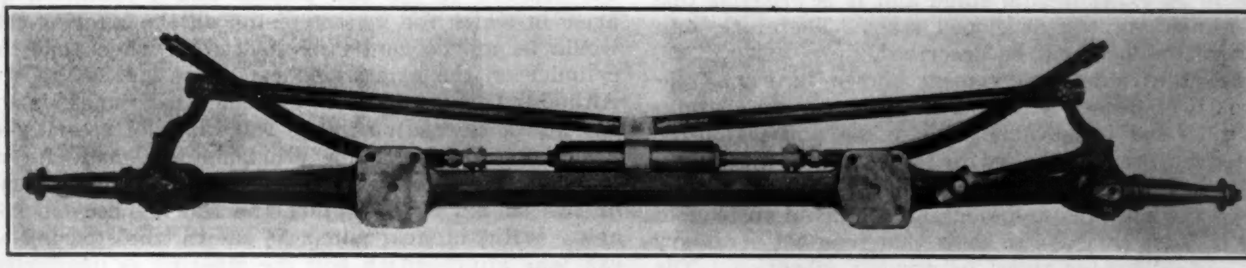

Fig. 3—Hydraulic Steering-Mechanism on Front Axle
A Divided Tie-Rod Is Attached to a Cylinder That Is Movable Transversely on a Piston and Hollow Piston-Rods Which Are Supported Immovably by Brackets on the I-Beam Axle. Flexible Copper Tubes Connect the Interior of the Cylinder, through the Hollow Piston-Rods, with Tubing on the Car Frame Which Communicates with a Pump at the Foot of the Steering-Column

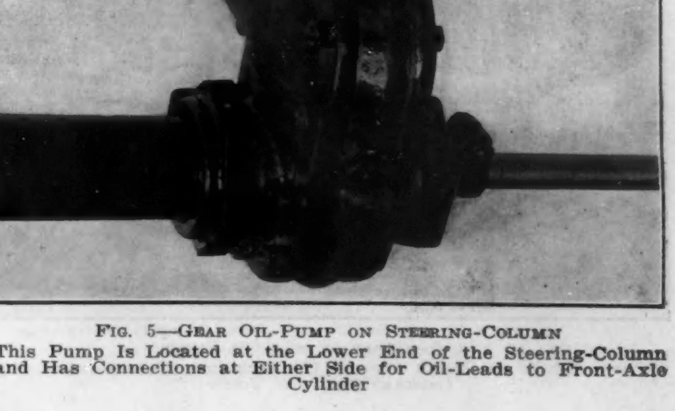

Fig. 5—Gear Oil-Pump on Steering-Column
This Pump Is Located at the Lower End of the Steering-Column and Has Connections at Either Side for Oil-Leads to Front-Axle Cylinder

back to the hypothesis that to prevent shimmy we should eliminate all backlash, at the same time maintaining steering control.

How Hydraulic Steering Is Accomplished

To attain these objects I have used the hydraulic system, which dispenses with mechanical joints and can be kept full of liquid, thereby avoiding looseness, and I have mounted the system on the front axle, where it is separate from and independent of the car frame. The results that have been obtained have demonstrated that this is a long step in the desired direction. At the first meeting of the Buffalo Section in the fall of 1924 R. B. Day, of the Goodyear Tire & Rubber Co., gave some demonstrations with a car fitted with a hydraulic dashpot located on the front axle which reduced shimmying but did not eliminate backlash. The hydraulic steering-mechanism possesses the same dashpot effect. I shall not discuss the details of the mechanism by which hydraulic steering can be accomplished, except in a limited way, because, in the developments I have carried on, the methods are in an experimental stage and it is probable that better means may be developed later. Therefore, only the general method will be described.

In the front axle arrangement shown in Fig. 3 the drag-link is dispensed with and the cylinder that operates the split tie-rod is movable on a piston and piston-rod supported by brackets bolted to the center of the front-axle I-beam. The cross tie-rods are fastened to the center of the movable cylinder and are solid instead of tubular because they are so short that it is not necessary to use large-diameter tubes to prevent vibration. The stationary piston-rod is drilled from either end and is connected by flexible copper tubes encased in rubber with the rigid piping secured to the frame and completing the connection with the steering-wheel pump or piston. A supply of liquid is carried in a tank on the dash, which may be the same tank as is used in the conventional hydraulic-brake system.

Main Cylinder and Master Pump

Details of the axle cylinder are shown in the sectional drawing, Fig. 4. The external construction of the oil-pump on the lower end of the steering-column is shown in Fig. 5, and the internal construction of the experimental model of the pump is shown in Fig. 6. Grooves are cut in the pump gear-teeth to prevent oil-pocketing, which they do without increasing leakage in the least. In pumps of this type the clearances must be kept at the minimum and the cost is greater than when the piston-displacement method is used. The latter method has one disadvantage, however; if a piston-pump is used on the steering-column instead of a positive gear-pump, any minute leakage of liquid past the piston in the pump or past the piston in the cylinder on the axle would destroy the relation of the two pistons and a condition might arise in which the master piston on the steering-column would be at the center of its stroke when that in the cylinder on the axle would be at one end of its stroke. Although this would be an extreme condition, it is apparent that a restriction in the full range of steering-angle would occur unless some provision was made for automatically compensating for leakage even though a month or two should elapse before the leakage became noticeable. With the gear-pump, as shown, the steering-wheel can take any position and the steering is unaffected by any minute leakage in the system.

[2] M.S.A.E.—Consulting engineer, Hewitt Rubber Co., Buffalo.

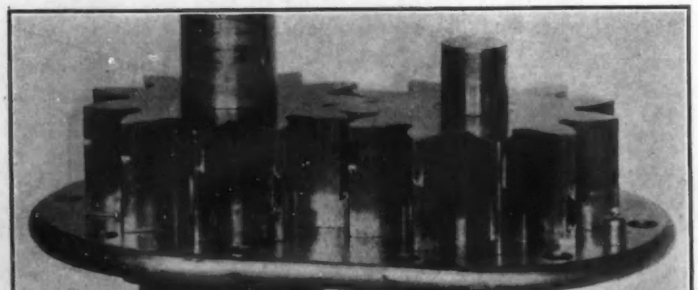

Fig. 6—Gears of the Oil-Pump
Grooves Cut in the Teeth Prevent Oil-Pocketing without Increasing Leakage Past the Teeth

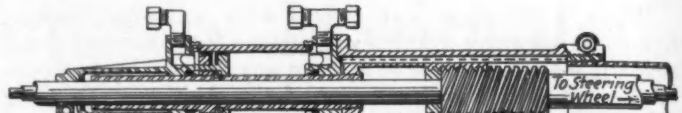

Fig. 7—Piston-Pump Operated by Thread and Nut
This Is a Cheaper Construction than the Gear Pump. The Piston Has a Slightly Greater Displacement than the Piston in the Axle Cylinder, and Any Relative Displacement of the Two Pistons Due to Oil-Leakage Is Corrected by Mechanism That Is Not Shown

Fig. 7 shows a cross-section of a cylinder and piston on a steering-column. The piston has slightly greater displacement than the piston in the cylinder on the front axle and any relative displacement of the two pistons is corrected by a mechanism that is not shown.

Any leakage of liquid from the system is replaced automatically from the supply-tank on the dash so that the system is kept full. The tank is connected with the pump or master cylinder on the steering-column and a check-valve is inserted in the connection just below the tank. The system sucks in through this valve enough liquid to replace what is lost by leakage.

It is apparent from the foregoing description that there is no inherent backlash in the steering mechanism and that there is no drag-link. Another important consideration is the geometry of the divided cross tie-rod as compared with a straight tie-rod. The steering-arm angles are practically 22 deg., or double the angle of the conventional construction. This is an important advantage as regards clearances with four-wheel brakes. The geometry of the hydraulic system is much nearer the theoretical condition than that of the mechanical steering-system; in fact, it is perfect at 40 deg., and 50 per cent better than the conventional system at 20 deg.

THE DISCUSSION

J. F. Palmer[2]:—The problem of shimmying and tramping is of great interest to the tire man and, while Mr. White has approached the subject from the automobile-engineer's standpoint, I have studied it in the last year from the tire standpoint and have come to the conclusion that the trouble should be divided between these fields. Mr. White has demonstrated conclusively the effect of the steering connections on shimmying. My own conclusions have been reached from extended experiments. It is my experience that the amplitude of vibra-

tions in the tires synchronizes with the amplitude of vibrations in the springs and causes the familiar phenomena of shimmying. Amplitude of vibration in the tire can be governed by altering the cross-section to an ellipse whose major axis is parallel with the axis of the wheel. This increases the carrying capacity by increasing the area of contact of the tire with the road, which gets back more nearly to the condition of the high-pressure tire. I have succeeded in demonstrating conclusively that a tire made on that plan will steer easier and will eliminate low-speed shimmying and tramping. I have tested a car, equipped with high-pressure tires, that would shimmy under almost any conditions when the pressure had been reduced somewhat.

QUESTION:—What was the over-all mechanical efficiency of the gear-pump compared with the thread-and-nut piston-pump?

MR. WHITE:—We do not know, as yet. We are using the same ratio, namely, 2¼ turns of the steering-wheel, for full front-wheel travel.

QUESTION:—Do you get as much reversibility with the gear-pump as with the thread and nut?

MR. WHITE:—I do not think so. The worm-lead approaches an absolute lock as the gear-ratio increases. The gear-pump shown is reversible, but apparently not to the same extent as the average worm-gear. The worm-gear ratio is increased by reducing the lead, and therefore the irreversibility will vary as the cotangent of angle of the lead. To increase the gear-ratio of the pump, you simply cut down the width of the gear face; the irreversibility increases inversely as the gear width. That is one of the reasons why we prefer the cylinder on the steering-gear and use a rapid thread and nut to actuate the piston, which gives the same condition as a worm plus the dashpot effect of the hydraulic system, which dampens out small impulses much more effectually than would the dashpot with a conventional steering-gear.

QUESTION:—Is it not a fact that the front wheels are toed-in to correct the error caused by the camber of the wheels?

MR. WHITE:—I think we are facing a change so far as camber is concerned. I cannot see the necessity of having the wheels inclined when using balloon tires, especially as our roads are not crowned so much as they used to be. I do not think we can get rid of axle rake, because that is necessary to make the wheels recover from a turn.

QUESTION:—Is not that also due to the relation of the angular displacement of the two steering-pivots? We never lay out this angular relation to give theoretically correct steering, inasmuch as the center-lines of the two steering-pivots do not intersect on an extended center-line through the rear axle in a plane normal to the center-line of the car.

MR. WHITE:—It would depend on the length of the wheelbase, of course. You can correct also by the length of the steering-arm; the shorter the arm the more accurate the geometry, but the more pronounced the backlash becomes.

QUESTION:—What happens when one of the pipe-lines breaks? Is the steering mechanism out of commission?

MR. WHITE:—Absolutely. What happens when the drag-line in the conventional design breaks? The only thing to do is to make it just as safe as any other part of the car.

A MEMBER:—The likelihood is that the break would be very gradual.

MR. WHITE:—That is true. We have found that, in driving for a month, after the tank supply is exhausted a little backlash will develop, which is the warning to fill the tank.

QUESTION:—Do you get any different condition with the higher viscosity of the oil in the winter?

MR. WHITE:—We find that about 67 per cent of castor oil and 33 per cent of alcohol make a solution of about the same density as a 50-50 mixture in winter in hydraulic brakes. In summer we use 50 per cent of alcohol and 50 per cent of castor oil.

I believe that the torque of the engine has considerable to do with shimmy.

A MEMBER:—I think the important thing that Mr. White has done is to eliminate the drag-link. I believe that most of the trouble I have had was due to the link.

MR. WHITE:—I think we could go even further and eliminate the springs in the ends of the divided tie-rods.

MR. PALMER:—I think so, too; the spring in the balloon tires is enough.

COMMODITY RESEARCH

IN its last analysis sound business judgment cannot be acquired by the use of convenient aids to the business imagination. Such valuable aids as are derived from research must themselves result from judgment applied intelligently to the state of facts that requires consideration. Judgment is developed by trial and error in actual experience. However much we may wish to guard against failures in judgment, a certain amount of such failures is inevitable; but the real question is not so much that of making or avoiding mistakes, as the question of not making the same mistake the second time.

The field of commodity research is one of immense complexity, often involving vastly greater difficulties than are readily admitted to be inherent in the particular questions that demand solution. Commodity research without actual contact with the existing conditions of production and distribution is likely to be futile. In rubber research, for illustration, the present question of uppermost concern is that of new sources of raw rubber, not subject to the operations of the Stevenson Act fostered by the British Government. One cannot possibly hope to understand this situation without a thorough knowledge of the origin and effects of that type of restrictive legislation; nor can one hope to understand the rubber situation generally without some historic background of the earlier dependence upon wild rubber, which was in the nature of pure exploitation of the accessible tropical forests, as opposed to modern methods of plantation production, which is in the form of a skilful, scientific method of agricultural development. All business involves problems of this kind, and he is a fatuous theorist who ignores the fundamental facts of the situation with which he has to deal, contenting himself with the elusive appearance presented by elaborate tables of statistics and beautifully drawn but hopelessly confusing charts, and assuming that he can thus discern the hidden laws or fundamental tendencies that determine the success or failure of business operations.—From an address by F. L. Hoffman before Babson Business Conference.

Basic Factors of Production

By K. T. Keller[1]

Production Dinner Address

WHAT should interest us most is our work; if that is not true, we should not be engaged in it. The production side of the automotive industry can be divided into the three major divisions of quality, quantity and cost. I have stated them in that order because I believe that quality is the prime feature of the automobile. You cannot have a business unless you have quantity, and then the management wants you to make the product cheaper and you have cost. Quality is first; because, without a sound product, you can have no permanent business.

When I entered the business, the progressive carriage manufacturers were looking for someone with the ability to build them an engine that they could use in their carriage works. The chassis, being added to the line that they knew how to make, soon proved to be the weak link in the chain. This Society is built up from the men who came forward and strengthened that weak link until, today, the chassis is the finest piece of development that we have seen. The automobile body has come along, but still much development work remains to be done on both the chassis and the body.

It was the realization that a man is buying transportation and not plush and paint that brought about the development of the automobile. When I say "quality," I do not refer to nickel-plating a handle, putting on numerous coats of paint, and the like; I refer to turning out a car that delivers transportation. Quality depends on organization and discipline. You must know what you want to make and what you expect of the product. I think the average man in the factory knows what is expected of the component parts of the car. I have always inclined to the point of giving your workmen their tasks to do and expecting them to turn out a car that is right. In other words, if I am bolting a fender to a chassis and some automotive expert is standing there to see that I am doing it right and he knows more about it than I do, the management ought to let him do it and take me off the job. Of course, that is true only within limits. Regarding machine tools, for example, a man should be alongside to inspect the product, but such men constitute a team. After we have given them an opportunity to build an automobile, someone should be provided to protect the customer. I have picked our best mechanic for the job, and he reports direct to me. Such a man must be supported, even though he is apparently too tight with the production men; afterward, you can have a private talk with him and point out where you think him in error. Any man can get things completed if he goes down, rushes things through, shoves the product into a freight car and sends the freight car out. But you must have quality. Quality results in the satisfaction of customers and in good will, with sales as a reward for good will, provided you work on the selling end too.

When you get this "quality" idea soaked into your organization, then build automobiles when wanted. Consider quantity. It is also a matter of organization, but the organization that you need for quantity production is the organization that can look ahead. If you want to build 1000 automobiles per day next January, somebody in your organization must be looking ahead and planning for that result.

The men represented here have done considerable of that planning. So far as the machine-tool capacity goes it is an easy thing to plan, since you have your time study, your operations and the like laid out. It is a simple matter of arithmetic. But that is only one side of the planning. The other side involves looking ahead with an eye to quantity, with a view to producing more parts and doing it more quickly and more cheaply. This desire to produce more quickly and cheaply has been responsible for more delay in production than anything else. The man doing this looking ahead also looks for a machine-tool builder who is anxious to sell his equipment. The purchasing agent buys the equipment. The machine-tool builder promises delivery at a certain time. It is not made as expected, you have delay and your cost has gone up. It is often difficult to know whether to try the new idea or to go ahead with the old method. Each case needs to be decided on its own merits.

Control of Material and Cost

After the machine shop comes the assembly line. No one knows today what one can get out of an assembly line. We find 50 cars per hr. and 20 cars per hr. with practically an equal cost on each, and we find at 10 cars per hr. some cars poorer than others produced at the rate of 25 cars per hr. You must determine on some point and then go out and reach it. I say that no one knows what one can get out of an assembly line because the thing that controls production on an assembly line is getting material to that line. The man who controls material is a very important man, so far as quantity production is concerned. He does not merely make out the program; he must watch everything and know what is coming and what can be done. Someone in the material department must look ahead and know where every carload of material is and when it will arrive.

After quantity, then one must get cost. This cost situation constitutes a large undeveloped field. In the average plant, if you talk cost, they say "Yes, we have figures on the cost per car." I believe the average man in the factory is just as unfamiliar with the cost system as he is with the Bible. The figures are not set up so that he can understand them. I have found that a manager can get good costs and get them quickly, if he knows what he wants. That end of the cost business can be handled with a very small staff.

Cost calculating shows various inaccuracies in the different systems. The portion of the cost that you have within your own hands to remedy lies in the "overhead." This means not only the overhead in the shop where you have a few inspectors and a few foremen, but it means the overhead of your trucks, your accounting department and your purchasing department. The average plant that is running with an overhead of 150 per cent generally is doing a very good job. We have operated plants as low as an 87 per cent, and as high as a 200 or a 300 per cent overhead. Percentage figures for overhead mean nothing to me. To take a proper view of

[1] Vice-president and general manager, General Motors of Canada, Ltd., Oshawa, Ont., Canada.

overhead, you should take each individual man, go around the circle of employes and then start over again. You should ask: What is he doing for the money that he gets? I take the position with our control organization that the only thing its members are there for is to make the work easier and better for the fellows who are actually putting the cars together and putting on the paint. If you and I cannot do something to make the workman's task easier and better for him, then we have failed as executives. Many men creep into the overhead account who should not have left production. There is room for everybody, provided we can all do something that is constructive. To do something constructive, you must work at your job and make your work the prime thing in your life. If you cannot do that, get out. The best recommendation that a man can show me with regard to fitness for promotion is proof that he is handling his own job well. This, of course, is within limits.

Human Elements

I think the chief mark of a man's loyalty is for him to give service for the money that he is drawing. Automobile companies need us as much as we need them. No company employs you just because it likes you. If the company pays you $100 per month, it is because it expects you to do $200 worth of work for it. Therefore, I think that this matter of overhead is one of prime importance to engage the attention of any manager today. Do not take it out on the fellow who is making $4 per day and sweating like a hound. Place your men on the work that they can do to the best advantage. Get greater volume and decrease prices; everybody will have work anyhow.

Each plant presents a different aspect. In my 14 years with the General Motors organization I have been in numerous different plants. Each plant presents a different picture. When you have gone from one institution to another institution, or to another plant of the same institution, do not take the same gang and do the job just as you did it before. At each place, you will find someone who knows more about it than you do yourself. Find those fellows and encourage them and build them into your organization. When you get to the place where you know all about the job that you are doing, go out and get another one. Learn as many things as you can before you get too old and too much weighted down with responsibilities. It does not hurt you to get around, provided you are learning something.

It is deplorable in the industry to see a man progress as high as, say, a superintendent, and then see him strike a stone wall. Every manager should help his men along, develop them. To me the strongest recommendation for a new position is for a man to have handled his present position 100 per cent effectively. This is true within limits, of course. Developing a man for a higher position and promoting him to it is much better than getting rid of him, getting someone else and waiting a long while to find out what the new man can do. There is a great opportunity in this industry to develop young men. Keep them moving along.

With these thoughts in mind and knowing that we shall need a number of able men in Canada in the future, we take six young men of good family and high intelligence each year, and put them through a 2-year course, paying them 35 cents per hr. We start them through the plant, not only through the assembly part but through the painting, the trimming, the service and the maintenance departments; we also educate them in meeting the public. Some of them show a tendency to develop into the factory end of the business, others into the public-contact end. In the second year, we weed out those who do not like the work or who are not making progress. Six men per year is a number sufficiently small to enable us to give personal attention to them, which is an important thing in a course of this kind.

In looking back over my experience, I see men who took a great personal interest in me. I want to thank them for it. They kept me steady when I had rabid ideas and they have helped me in my work by showing me how things were done. I want to thank the young men who push us along. Competition between men in the field exists just as much as between the cars that are being sold. Lend a helping hand to the younger fellows. Encourage their ideas.

INTERNATIONAL TRADE RELATIONS

THE United States is now the leading creditor nation of the world. Assuming conservatively an average return of 6 per cent on the $9,500,000,000 invested abroad, we shall receive an annual income of about $600,000,000. This means that foreigners will be obligated to send us this amount of goods or services, without this Country being obliged to export in return. If the foreign debts to the United States Government are included, and an interest rate on these of about 4 per cent, including amortization, is assumed, the annual payments due this Country amount to more than $1,000,000,000. In 1924 the total imports of merchandise amounted to $3,610,000,000, which shows the relative magnitude of the interest and dividend payments due us annually.

The transfers of large sums of money between different countries—transfers made necessary by reparations payments, inter-Allied debts and other obligations — provide their own ways and means. In fact, the present loan operations have come into existence in part to facilitate such transfers. However, at the present rate of loaning, the amount of money that this Country is sending abroad more than offsets the amount payable to this Country. Thus the supposed problem of transferring funds to this Country does not at present exist.

If any problem existed, it would be that of transferring to Europe the $1,000,000,000 a year of new capital that Americans are investing in Europe. The transition to the reverse situation, where earnings on funds abroad are greater than new capital invested there, will take care of itself without artificial help, although it is of course obvious that a high tariff renders this operation more difficult. The transition will come about gradually, and may not come for a long time. As the interest payments due this Country increase in size the probability is that foreign goods will compete to an increasing extent with domestic goods, causing some readjustment of our own industries.—J. P. Young in *New York Times*.

Some Aspects of Aircraft-Engine Development

By G. J. MEAD[1]

AERONAUTIC MEETING PAPER *Illustrated with* PHOTOGRAPHS

ABSTRACT

INFALLIBLE performance and economical operation are the bases of successful commercial flying. Airplanes, having passed through the experimental and demonstration periods, must now prove their usefulness. Heretofore, because of military requirements, designers have fostered the use of power rather than refinement of design to obtain performance, but commercial operation demands efficiency, and in each of the four essentials, namely, dependability, size, total powerplant weight and cost, opportunity for decided improvement still exists.

The requirements and limiting factors of each of these essentials are discussed in turn and the conclusion is drawn that a relation exists between the amount of thrust delivered to the air and the weight put into an airplane for its propulsion. To obtain the best over-all performance, if these terms are considered as a fraction, the numerator should have the maximum and the denominator the minimum value.

The suggestion is made that a more significant measure of efficiency than the weight per horsepower of the engine alone would be the wet weight of the engine per horsepower plus the weight of the cooling-system per horsepower plus the combined weight of the fuel and oil per horsepower per hour. The figure thus obtained would have no value, however, except as an indication of the over-all efficiency of the powerplant.

The general development of airplane powerplants is outlined, the various engines in vogue at present are classified into groups according to their horsepower, and the assertion is made that the air-cooled type of engine, having already displaced the water-cooled in the 200-hp. class, is likely to do so in the 400-hp. class. Designers of water-cooled engines are said to be endeavoring to overcome the handicap of excessive weight in engines of this type, but air-cooled engines, because of their greater dependability, are considered superior for commercial purposes.

In addition to increased dependability and reduced weight, the radial type of air-cooled engine makes possible an aerodynamically superior and symmetrical fuselage and gives a high center of thrust that allows ample propeller diameter.

In motor-car work, dependability and light weight are less essential than in the aeronautic field; consequently, the urge to develop them has not been so pressing. A leaky radiator in a motor car can be easily repaired but, if it necessitates a forced landing by an airplane, may lead to disastrous results.

Detailed descriptions, accompanied by illustrations, are given of a large number of American and foreign types of aircraft engine.

THE airplane is entering a new stage of development. It passed through the purely experimental stage when the Wright brothers proved that man could fly, and the demonstrating period when the airplanes proved their usefulness. The present development must insure infallible performance and economical operation in order that flying may be placed upon a commercial or paying basis. Every pound of plane or of powerplant weight must be justified. Thus far, the powerplants used have often been inefficient, especially at part throttle, or too large for the work to be done. The effect of purely military requirements has been to foster the use of power, instead of refinement, to obtain performance, a condition that is certainly not economical, for satisfactory commercial operation requires all-round efficiency of the powerplant. Fortunately, an opportunity exists for decided improvement in this direction, especially in four essentials, namely, dependability, size, total powerplant weight, and cost.

DEPENDABILITY

Dependability is the most important of all the requirements, for the whole success of flying hinges upon it. Any improvement is valueless if it detracts in any way from this prime requisite. Unfortunately, it is often overlooked in an endeavor to catch up with the "weight-per-horsepower" bogey. Dependability involves experience in design, intelligent engine-rating, conscientious manufacturing, and proper service-care.

Simplicity is necessary, so that each item of equipment shall be scrutinized as to its essentialness. It is a well-known fact that proper care can be invited by good design and that parts that are inaccessible will receive little or no attention. Upon proper engine-rating depends, in large measure, the dependability of the engine, other things being equal. Here, again, to show a low weight per horsepower, ratings have sometimes been raised until the use of special fuels is necessary for satisfactory operation.

The proper commercial-rating should be such that the engine will run through a 50-hr. non-stop test at the rated power and speed, with standard aviation gasoline as well as with guaranteed fuel and oil consumption. No major repairs should be required at the completion of the test to return the engine to first-class condition. An engine capable of successfully passing this test will usually be good for from 300 to 400 hr. in the air before a top overhaul is necessary. Many designs are lightened to a point at which fatigue failures in highly stressed parts occur long before the engine as a whole has outlived its usefulness. In addition, gasket surfaces are reduced to the irreducible minimum, with the consequent oil and water leaks; pistons are shortened until their aspect-ratio is impossible; and studs are made so small that the conscientious mechanic with a wrench not shown in the instruction book can cause considerable damage. These extremes cannot be tolerated, nor are they even worthy of serious consideration until reasonable efficiency has been secured in other directions.

[1] M.S.A.E.—Vice-president, Pratt & Whitney Aircraft Co., Hartford, Conn.

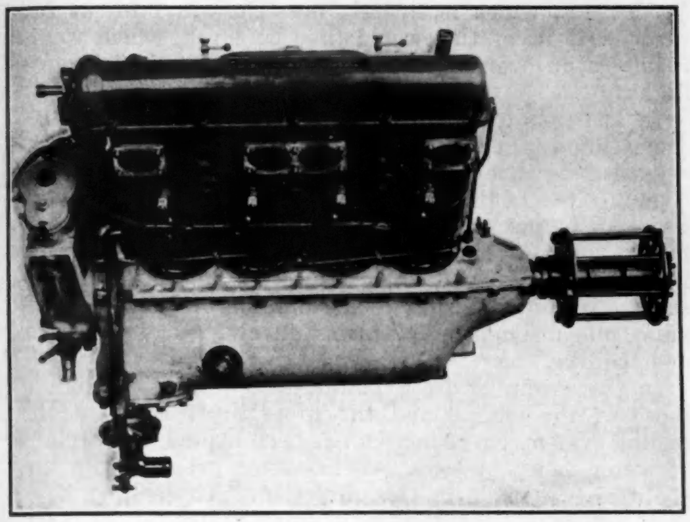

FIG. 1—WRIGHT E-4 EIGHT-CYLINDER V-TYPE ENGINE
This Water-Cooled Engine Was Practically the Standard in the 200-Lb. Class 2 Years Ago

SIZE

There is a certain economical size of engine for every airplane requirement. The use of power alone to secure performance, naturally, is uneconomical. It is as useless to overpower an airplane as a tow-boat. In neither case will the performance be in proportion to the added power, beyond a certain point. Until now, few restrictions or none have been placed on the size of the powerplant used, as most of the requirements were military, where gain in performance was paramount, regardless of cost. Limitations are necessary, however, for developing over-all efficiency. At the present time, the Navy has both space and weight restrictions. As a result, Naval airplanes of the future will undoubtedly be more economical than would otherwise be the case.

Engine size depends upon the drag of the airplane, the performance required, and the efficiency of the propeller and of the engine. Reduction in drag is often the only way in which increased performance can be economically secured. The shape of the powerplant and its method of cooling affect the drag. Water radiators, with the shutters closed, frequently offer considerable resistance; likewise, the unsymmetrical fuselage shape required by certain types of engine. In determining the proper engine-size, the relation of the amount of power applied to the improvement in performance should be borne in mind.

At present, the available power-units are separated by approximately 100 hp., making it relatively easy to secure the correct size for a given service. The efficiency of the propeller influences the size of the engine, as the actual thrust developed, rather than the power of the engine alone, determines the performance. As engine-crankshaft speeds have increased and large relatively slow-speed airplanes are becoming common, the relation of the speed of the propeller to that of the airplane often becomes poor.

SPEEDS

Heretofore, when the speeds of the propeller and of the airplane were both relatively low, reasonably good propeller-efficiency was secured, at least 75 per cent being common. With the present trend of development, except in the case of high-speed airplanes, propeller efficiency is often poor, and sometimes considerably less than 75 per cent. This is a serious situation that can be corrected to some extent by proper propeller reduction-gears; it is probable that variable-speed gears will be used in the future, particularly with supercharged engines.

Engine size for a given power-output depends upon mechanical as well as thermal efficiency. With higher crankshaft-speeds and more accessories, especially engine-driven superchargers, friction horsepower becomes particularly important. This item remains practically constant and therefore affects the mechanical efficiency most seriously at high altitudes. It is equally important to obtain the maximum mean effective pressure from a given cylinder to get the best over-all efficiency. Extremes in speed and compression-ratio are sometimes resorted to in order to produce the required power-output, instead of providing proper means of filling each cylinder with the maximum-weight charge at a more normal speed. It is often supposed that high compression is synonymous with high power; on the contrary, it is sometimes an evidence of poor design. Some surprising power increases are possible in these directions.

POWERPLANT WEIGHT

It is particularly essential to consider the total powerplant weight for any given service. No single item entering into this weight can be considered to the exclusion of the others, if the minimum total weight is to be secured. In recent years the most attention has been given to the matter of the engine weight per horsepower, so that considerable development has been made along these lines and it is reaching the minimum value. I say "reaching" advisedly, as the absolute minimum will never be reached. The curve is flattening, however, so that no startling gains will probably be made in this direction in the near future.

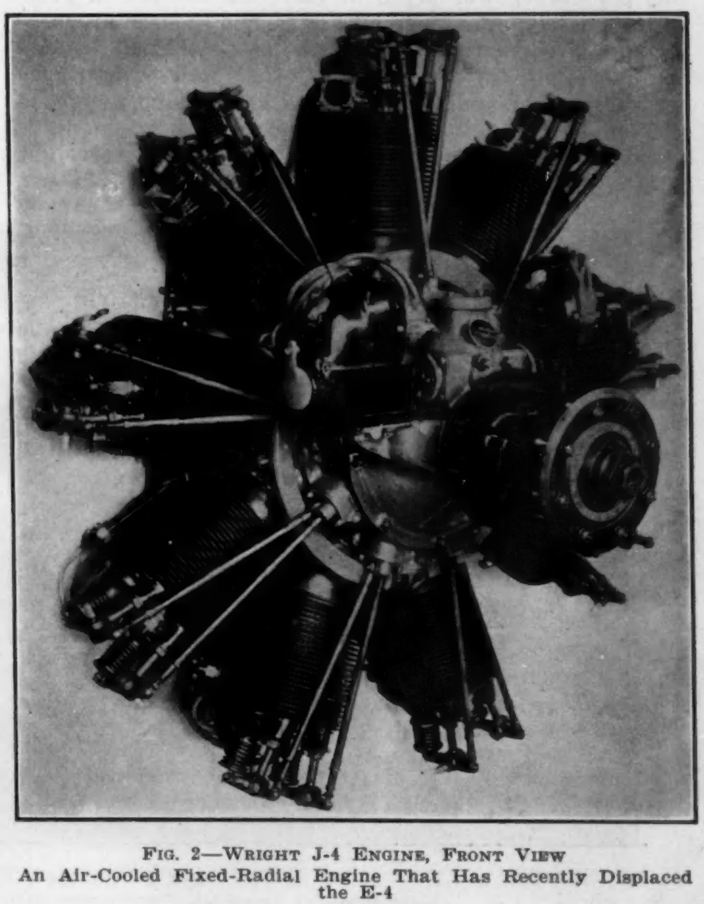

FIG. 2—WRIGHT J-4 ENGINE, FRONT VIEW
An Air-Cooled Fixed-Radial Engine That Has Recently Displaced the E-4

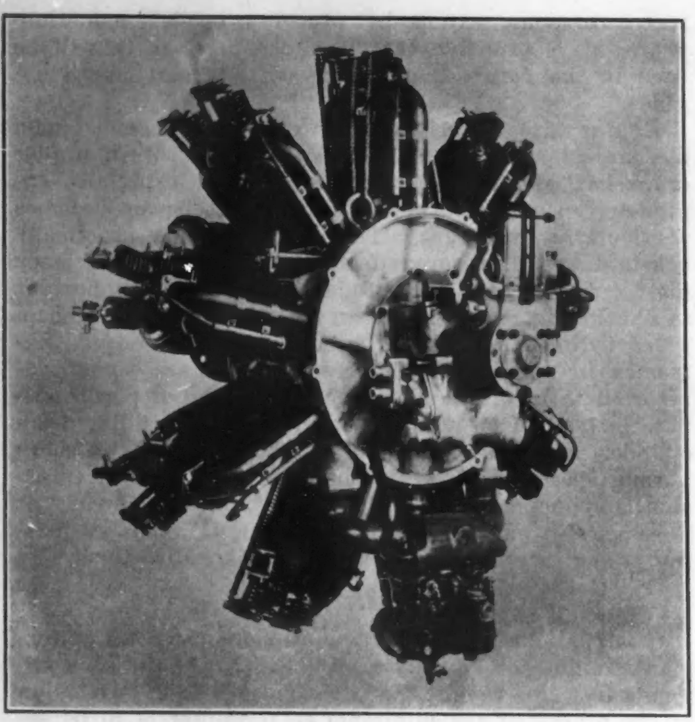

FIG. 3—WRIGHT J-4 ENGINE, REAR VIEW
The E-4 and the J-4 Have Approximately the Same Dry Weight and Power

One item of powerplant weight that is more important than the others, especially for duration service, is fuel consumption. This has not exactly been overlooked, but certainly has not been considered in the light of its true importance. An arbitrary figure of merit of 0.5 lb. of fuel per horsepower per hour has been considered good. Unfortunately, even this value is seldom secured at cruising-speed, where fuel economy is most essential. Added engine-weight, in other words, increased weight per horsepower, can well be considered, if a saving in fuel is effected by it. For example, suppose that 25 lb. were added to a 400-hp. engine, and that this additional weight made a difference in the fuel consumption of 0.1 lb. per hp. per hr., which is entirely possible. In 1 hr. at full throttle 40 lb. of fuel would thus be saved, which would result in an over-all saving of 15 lb. in a single hour's flight.

In addition to fuel consumption, oil consumption becomes important on long flights. It has often been disregarded because of the small amount of oil used relatively to that of the fuel. On the other hand, any saving here can be put into additional pay-load. It is interesting to note, in this connection, that low oil-consumption is sometimes difficult to secure with high crankshaft-speed. In contrast to high-consumption difficulties, minimum oil-consumption problems involve excessive wear and the like.

In the group of fixed powerplant weights, including those of the engine and the propeller, is that of the cooling system. No reduction has been made in the weight of water-cooled systems, so that some progress can undoubtedly be made in this direction. Air-cooling, however, offers a considerable saving, ordinarily between 0.65 and 0.75 lb. per hp. At present, in no other way can such a reduction be made in the fixed weight.

Cost

The initial cost of the powerplant depends principally on the quantity of the production. It is undoubtedly true that the sales price is in the inverse ratio to the number of engines required. The use of air-cooling eliminates the cost of the radiator and some cost in the airplane structure and, since the costs of manufacture of air and water-cooled engines are similar, this makes a distinct saving in the total initial cost. Low operating-cost in some ways is automatically provided for, if the minimum powerplant weight is secured, as the quantities of fuel and oil used enter into this figure. Low maintenance-cost is more or less directly proportional to the excellence of the design. Simplicity is as essential as it is necessary for maximum dependability.

Relation of Thrust to Weight of Powerplant

From the foregoing it will be seen that a relation exists between the amount of thrust delivered to the air and the weight put into an airplane for its propulsion.

FIG. 4—VOUGHT UO-1 NAVY AIRPLANE
Considerably Increased Performance Has Been Secured with Air-Cooled Engines

Figuratively speaking, this might be considered as a fraction in order properly to relate the importance of the various items involved. To obtain the best over-all performance, the numerator should have the maximum value, while the denominator should have the minimum value. In this way, it will readily be seen that propeller efficiency is of very great importance; likewise, all the items entering into powerplant weight. To judge better the relative merits of various powerplants, it is time that a more significant measure of efficiency should be used than the weight per horsepower of the engine alone. Powerplant weight per horsepower is a much more worthwhile figure.

It is suggested that the net weight of the engine per horsepower plus the weight of the cooling-system per horsepower plus the combined weight of the fuel and the oil per horsepower per hour be used for this purpose. This figure is of no value except as an indication of the over-all efficiency of the powerplant. True importance is not attached to either the fuel or the oil consumption in this figure, if long duration is to be considered. On the other hand, for general comparative purposes, it is distinctly more valuable in placing the various values in their proper light than engine weight per horsepower. Figures of merit of this kind for most American engines are contained in Commander Wilson's excellent article[2].

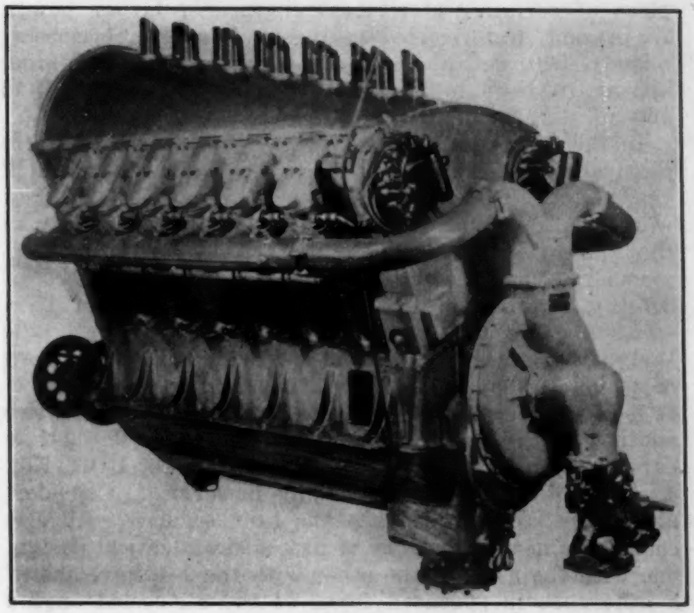

FIG. 5—AIR-COOLED LIBERTY ENGINE, THREE-QUARTER REAR VIEW
Originally the Standard in the 400-Lb. Class. Air-Cooled Cylinders of 4⅝-In. Instead of 5-In. Bore Are Now Used

GENERAL DEVELOPMENT

In view of the foregoing, it will be interesting to review recent powerplant development and to note its trend. Data concerning powerplants of various types are presented in Table 1. It should be borne in mind that some arbitrary standards have been set up as to powerplant sizes. Heretofore, all engines fell into three classes: namely, 200, 400 and 600 hp. Owing to the introduction of air-cooling and the consequent saving in weight, somewhat smaller power-units are taking the

[2] See *U S. Air Services*, February, 1925, p. 15.

TABLE 1—ENGINE DATA

Class, Hp.	Name	Type	Cooling	Number of Cylinders	Bore and Stroke, In.	Displacement, Cu. In.	Horse Power	Speed, R. P. M.	Compression Ratio	Mean Effective Pressure, Lb. per Sq. In.	Weight, Lb.	Powerplant Weight per Horsepower, Lb.[a]
200	Wright E-4	90-deg V-type	Water	8	4.710x5.110	718	200	1,800	5.30	122	470	3.20
	Wright J-4-A.	Fixed Radial	Air	9	4.500x5.500	786	200	1,800	5.00	112	470	2.35
350	Wright R-1200	Fixed Radial	Air	9	....	.....	350	1,900	....	...	.....	....
	Curtiss R-1454	Fixed Radial	Air	9	5.625x6.500	1,454	400	1,700	....	...	740	1.85
400	Standard Liberty	45-deg. V-type	Water	12	5.000x7.000	1,650	400	1,700	5.40	113	880	2.97
	Special Liberty	45-deg. V-type	Air	12	4.625x7.000	1,412	400	1,800	....	124	940	2.35
450	Wright P-2	Fixed Radial	Air	9	6.000x6.500	1,650	450	1,800	5.00	120	820	1.82
500	Curtiss V-1400	60-deg. V-type	Water	12	4.875x6.250	1,400	500	2,100	6.25	134	660	2.09
	Packard 1A-1500	60-deg. V-type	Water	12	5.375x5.500	1,497	500	2,000	5.50	...	720	2.20
600	Wright T-3-A	60-deg. V-type	Water	12	5.750x6.250	1,947	600	2,000	5.40	122	1,150	2.79
800	Packard 2500	60-deg. V-type	Water	12	6.375x6.500	2,489	800	2,000	5.70	127	1,150	2.39

[a] Fuel and oil weights were not included as many were unobtainable.

place of certain water-cooled engines of larger power. At present, water-cooled engines fall into three classes: namely, 500, 600 and 800 hp., while air-cooled engines appear in three other classes: namely, 200, 350 and 450 hp.

In the 200-hp. class, the Wright E-4 water-cooled engine, shown in Fig. 1, was practically the standard 2 years ago. This was a 90-deg. V-type eight-cylinder water-cooled engine. It was widely used, particularly in the Vought VE-7 airplanes of the Navy. It will be remembered that this engine made a duration record of 325 hr. at full throttle, which to date has not been equaled. The E-4 has recently been replaced by the Wright J-4, an air-cooled fixed-radial engine, a front view of which is shown in Fig. 2 and a rear view in Fig. 3. It is interesting to note that the dry weight of these two engines is the same; likewise, the power. The J-4 is extensively used in the Navy airplane Vought UO-1, Fig. 4, several hundred of them being in service. Considerably increased performance has been secured with air-cooled engines. Airplanes of practically identical design, one with the E-4 and the other with the J-4, have shown a difference in speed in favor of the air-cooled engine of 15 m.p.h.

Taking the E-4 airplane as a single-seater and the J-4 as a two-seater, the performances are practically identical. This would seem to indicate that not only is a saving due to the reduction in powerplant weight effected, but an increase in performance from the reduction in drag, due both to the better form of the fuselage and to the reduced resistance of the cylinders, as compared with those of an engine having a water-cooled radiator.

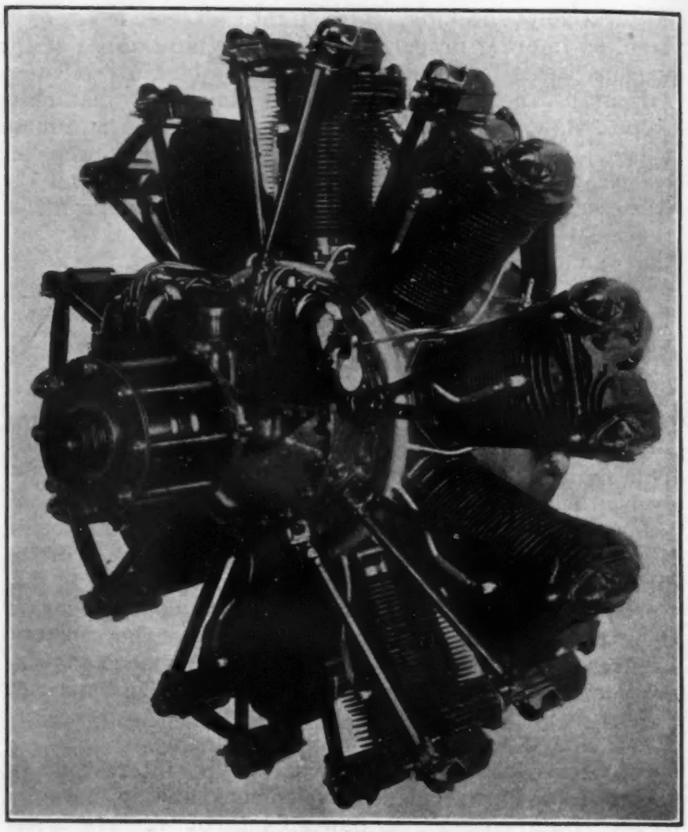

Fig. 7—Wright P-2 Engine, Front View
This Engine Is in the 450-Lb. Air-Cooled Class and Is the Largest Air-Cooled Radial Engine Now Built in This Country

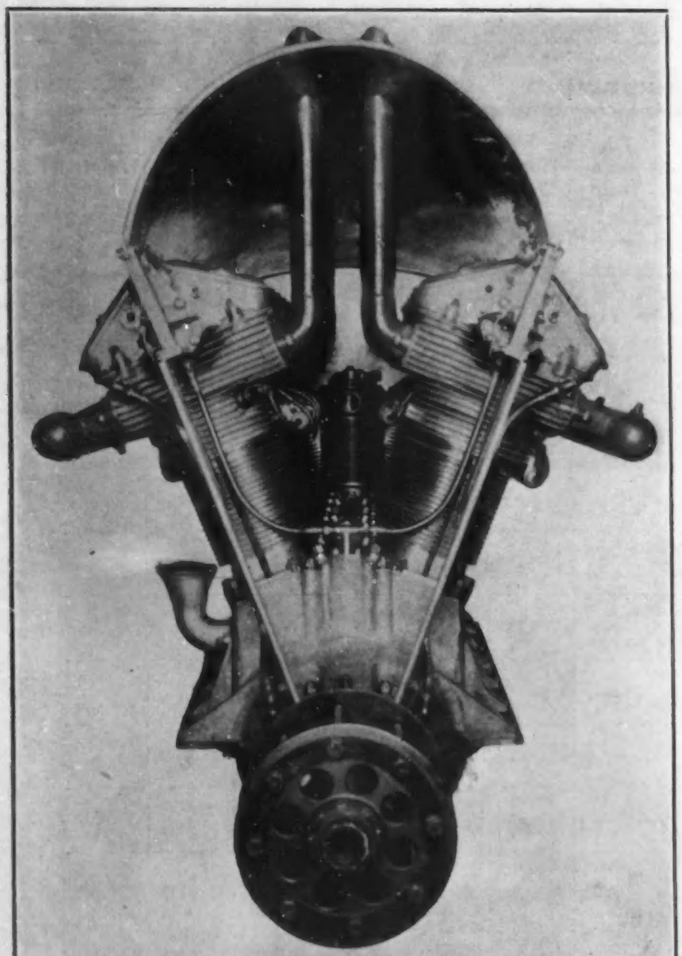

Fig. 6—Air-Cooled Liberty Engine, Front View
The Cylinders Are Interchangeable with Water-Cooled Cylinders

The Liberty Engine

In the 400-hp. class, the Liberty engine originally was standard. This, as is well known, is a water-cooled 12-cylinder 45-deg. V-type engine. The engineering division of the Air Service has developed air-cooled cylinders with 4⅝-in. instead of 5-in. bore for the Liberty engine, a three-quarter rear view of which is shown in Fig. 5 and a front view in Fig. 6. The cylinders are interchangeable with the water-cooled cylinders. In conjunction with them a rotary distributor is used, having a single carbureter. In this engine, the exhaust is on the inside and the intake-system on the outside. The cooling air is carried through the center of the Vee and is distributed outwardly past the cylinders. The engine develops 400 hp. at 1800 r.p.m. and weighs 940 lb. This weight may seem large in comparison with the dry weight of the Liberty engine, but comparing it with the weight of the Liberty engine and its cooling-system, some 1170 lb., the value is low.

The 400-hp. class, as previously noted, has been split into three classes: namely, the 350-hp. and 450-hp. air-cooled classes and the 500-hp. water-cooled class. A new Navy development is the Wright R-1200, a 350-hp. nine-cylinder air-cooled radial-engine. The Army Curtiss radial also comes under the 350-hp. class. This engine, known as the R-1454, is a development of the Wright R-1 built in 1920 and has the same displacement as the original R-1. The cylinders were developed by S. D. Heron, of McCook Field, and have enclosed valve-gear and a rotary distributing-system. Although the engine is still in the development stage, it has satisfactorily passed a standard 50-hr. test.

Largest Air-Cooled Radial-Engine

In the 450-hp. air-cooled class is the Wright P-2 engine, the largest air-cooled radial-engine being built in this Country. A front view is shown in Fig. 7 and a three-quarter rear view in Fig. 8. As a matter of fact, it has a larger cylinder-bore, namely, 6 in., than any other air-cooled engine in existence. The valves are located in a plane at right-angles to the crankshaft, both the exhaust and inlet ports being at the rear. Enclosed valve-gear is used, and a rotary distributing-system, incorporated into the engine, is capable of some supercharging. This engine was developed for the Navy and will probably be used in weight-carrying airplanes. It has been flown in a Douglas DT-2 airplane, replacing the Liberty engine previously used and showing a gain in speed of 7 or 8 m.p.h. and a reported increase of ceiling of 2000 ft. It should be borne in mind that this is a large airplane and was not originally designed to take full advantage of the weight saving possible, consequently, the difference in performance is relatively low.

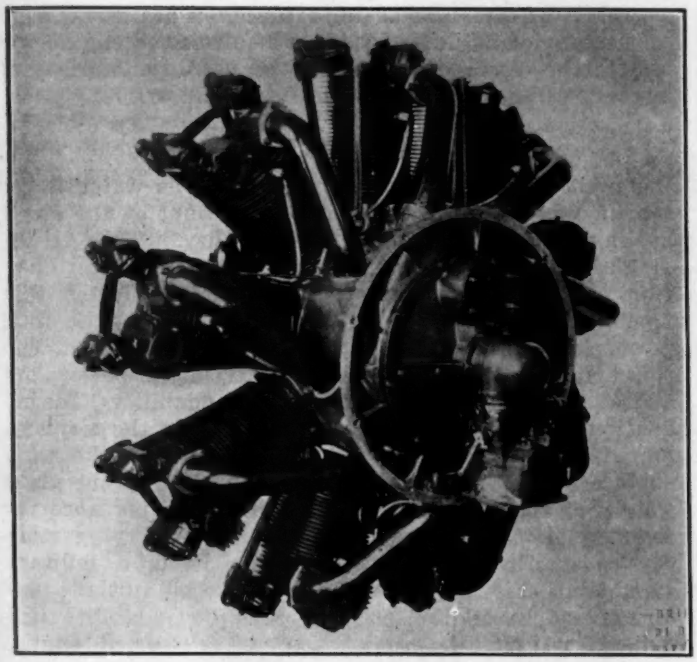

Fig. 8—Wright P-2 Engine, Three-Quarter Rear View
Replacing the Liberty Engine in a Douglas DT-2 Airplane, It Showed a Gain in Speed of 7 or 8 M.P.H. and an Increase of Ceiling of 2000 Ft.

In the 500-hp. water-cooled class comes the Curtiss V-1400, shown in Fig. 9. This is the latest engine to take the air, and is used in some of this year's Pulitzer Race entries. It is a development of the well-known D-12, but has 22 per cent more displacement. It is understood that this engine will be available both with and without propeller reduction-gears.

The Packard Company has developed another new engine[8], known as the 1A-1500, as a successor of the No. 1237 and the No. 1300 engines made by the same Company. These engines are made either with direct drive or with reduction gearing, and are inverted. Two of them of the geared type were used in the PN-9 on the trans-Pacific flight.

Both engines are of a distinctly high-speed type, being capable of crankshaft speeds of about 2500 r.p.m. They are particularly adaptable to pursuit airplanes, not only on account of their high power-output and low weight, but also on account of their small over-all dimensions.

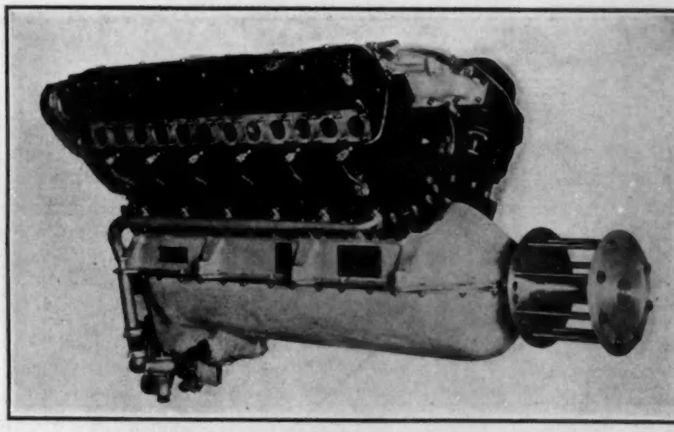

Fig. 9—The 500-Hp. Water-Cooled Curtiss V-1400
The Latest Engine To Take the Air and Used in Some of This Year's Pulitzer Race Entries

Wright 12-Cylinder Engine

In the 600-hp. water-cooled class is the Wright T-3A, a 12-cylinder 60-deg. V-type water-cooled engine, originally known as the T-2, with a rating of 500 hp. at 1800 r.p.m., but now rated at 600 hp. at 2000 r.p.m. A view of it is shown in Fig. 10. This engine is a Navy development for torpedo and bombing airplanes. More than 150 of these engines are in service, principally in the C.S., the S.D.W., and the PN-7 types of ship. Two of these powerplants in a PN-7 airplane accompanied the fleet, winter before last, to South America and return, without any overhaul, covering the entire distance under their own power and being away from their home station for 4 months.

The 800-hp. class has been recently established by the Packard 2500, shown in Fig. 11. This is also a 12-cylinder 60-deg. water-cooled enginè, similar to the Packard 1500, and furnished in either direct or geared models. It has the distinction of being the largest water-cooled engine in service, and of having a remarkably low weight per horsepower.

A number of other engines are in process of development, among which are the Noble 5RA engine, a small five-cylinder radial of some 80 hp., and the Army's 1200-hp. air-cooled X-type engine. Remarkable progress has been made with propeller reduction-gears, for which

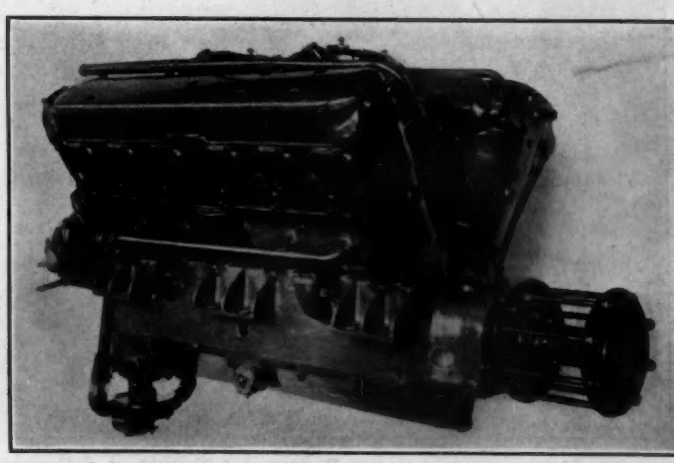

Fig. 10—Wright 600-Hp. Water-Cooled T-3A Engine
A 12-Cylinder 60-Deg. V-Type Engine, Originally Known as the T-2, with a Rating of 500 Hp. at 1800 R.P.M.; It Is Now Rated at 600 Hp. at 2000 R.P.M.

[8] See The Journal, March, 1925, p. 297.

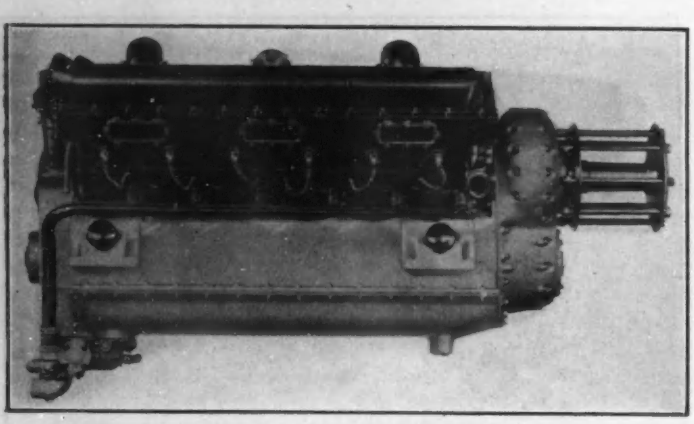

FIG. 11—PACKARD 1A-2500 GEARED ENGINE
This Engine Has the Distinction of Being the Largest Water-Cooled Engine in Service and of Having a Remarkably Low Weight per Horsepower

great credit should be given to N. H. Gilman, of the Allison Engineering Co. These gears are equipped with shock-absorbing couplings and Maag ground-gears.

SUPERCHARGERS

Considerable progress has been made in supercharging development under the direction of E. T. Jones, of the Army Air Service, with the cooperation of Dr. S. F. Moss, of the General Electric Co. The so-called side-type exhaust-driven supercharger and the engine-driven supercharger have resulted from this work. L. M. Griffith, of the National Advisory Committee, has developed the Root-type supercharger for the Navy. Experimental flights have shown it to be exceptionally satisfactory. From a military standpoint, supercharging is an absolute necessity; and it is likely to be almost as necessary for commercial work, on account of the increased speeds that are possible with its use.

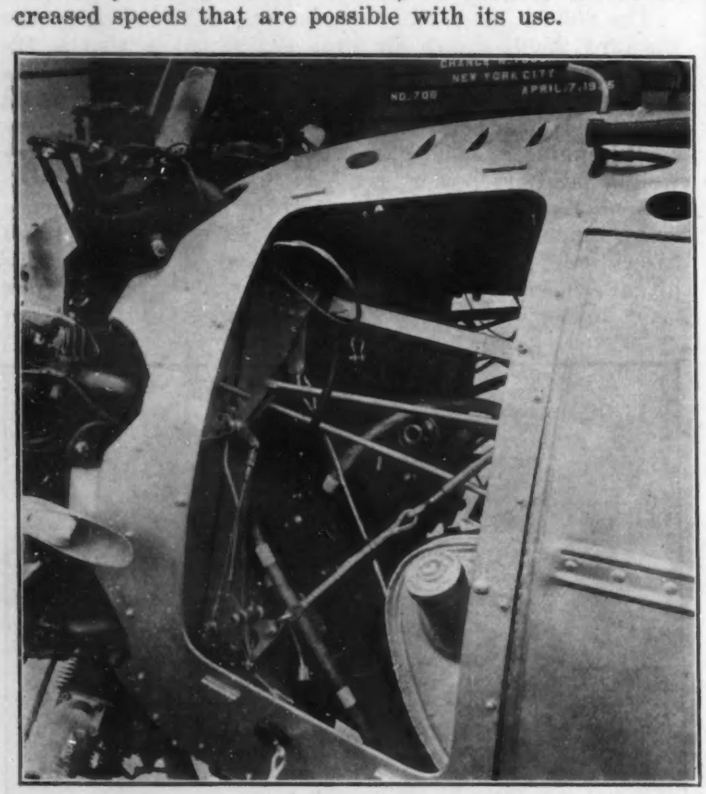

FIG. 12—METHOD OF INSTALLING WRIGHT J-4 ENGINE IN A VOUGHT UP-1 AIRPLANE
In Addition to Increased Dependability and Reduced Weight, the Radial Type of Air-Cooled Engine Makes Possible an Aerodynamically Superior and Symmetrical fuselage and Gives a High Center of Thrust That Allows Ample Propeller Diameter

HANDICAPS OF WATER-COOLED ENGINES

From this brief review it will be seen that the air-cooled type of engine has already displaced the water-cooled in the 200-hp. class, and is likely to do so in the 400-hp. class. The arrival of air-cooled engines has forced the development of water-cooled engines. Efforts are being made, by higher crankshaft-speeds and extreme lightening of parts, to make up for the handicap of the weight of the water-cooled system. On account of the high crankshaft-speeds, reduction gearing becomes necessary for propeller efficiency in relatively low-speed ships, resulting in further added weight.

In some instances, the weight of the water-cooled engine, with its cooling-system, is approximately equal to that of a similar-sized air-cooled engine. It is hard to predict how this matter will stand when the amount of experience with air-cooled engines begins to be comparable with that on water-cooled engines. It is obvious that the matter of dependability is greatly in favor of the air-cooled engine, a point that, for commercial purposes, is of the utmost importance. The development of the single and double V-types of air-cooled engine will enable this form of cooling to be used for engines of higher power than has heretofore been possible.

AIR-COOLING

Air-cooling is as logical for airplanes as water is for marine engines. Its simplicity, on account of the direct cooling, results in added dependability. This is the single most important reason for air-cooling. In addition, a considerable saving of weight is effected that amounts to approximately 0.7 lb. per hp. in the total powerplant weight. In no other way, at present, can this amount of weight be removed from the powerplant and at the same time increase its dependability. The reduction in powerplant weight is reflected in the airplane, both in the structure of the fuselage and in the wing surface for a given loading. The reduction in the gross weight of the airplane is of the utmost importance for commercial operation, as it provides for carrying more pay-load with a given powerplant. From a military standpoint, this saving results in increased airplane performance. In addition to increased dependability and reduced weight, the radial type of air-cooled engine makes possible an aerodynamically superior and symmetrical fuselage, a view of which is shown in Fig. 12, and gives a high center of thrust that allows ample propeller-diameter.

Heretofore, the drag of the cylinders was supposed to have been considerably greater than that of the radiator usually required for a water-cooled engine. This assumption has been disproved, as similar airplanes equipped with both air and water-cooled engines have shown a considerable increase in speed in favor of the air-cooled type, as has previously been brought out. This increase is particularly noticeable at high altitudes when the ordinary radiator is shuttered.

High speed is possible with the radial type of engine, as shown by the Gourdon airplane, which is reported to have reached a maximum speed of 224 m.p.h. with a 450-hp. radial-engine. Other advantages are numerous, such as the elimination of freezing and the constant cooling-value that is obtained. This item is something not usually thought of in connection with a water-cooled engine. It has been found, however, that scale formation often is responsible for overheated cylinders in the water-cooled type, particularly those of built-up welded steel.

Motor Cars versus Aircraft

With regard to air-cooling, the question is often asked, Why has it not been more widely used in other automotive work? Several motor-car companies have, at one time or another, undertaken the development of air-cooled cars, but at present only one company has been uniformly successful in this field. The answer to this question is that the two principal advantages gained by its use in aircraft, namely, increased dependability and reduction in weight, are not so essential in motor-car work. There was, therefore, not the urge to develop this type of engine that is present in the aeronautical field. Moreover, as the water-cooled engine was satisfactory for cars and as the majority of experience had been had with this type, it was only natural that car development should be along the line of water-cooling. It is not a serious matter in an automobile if the radiator leaks and the water runs out, as it is necessary only to stop and refill it. The occupants of the car suffer no damage. This, however, is not the case in the air, when a failure in the cooling-system makes necessary a forced landing, which is not always possible without injury to the occupants of the airplane.

Motor-car work also has another requirement that has not yet become essential to aircraft work, namely, extreme silence of operation. Undeniably, it is more difficult to make an air-cooled engine quiet than a water-cooled engine, because of the necessity for a blower in car work, for the distribution of air at sufficiently high velocity for proper cooling. This is required for low-gear work especially, when the engine is developing the maximum power and the minimum air-velocity is available. In an airplane, a minimum air-velocity of from 60 to 70 m.p.h. is available, but this, of course, is not the case in a motor car. With these points in mind, it is possible to see readily why air-cooled motor-car engines have not been more widely used. No doubt the experience gained and the success achieved with air-cooling in aircraft work will encourage the further development of air-cooled motor-car engines.

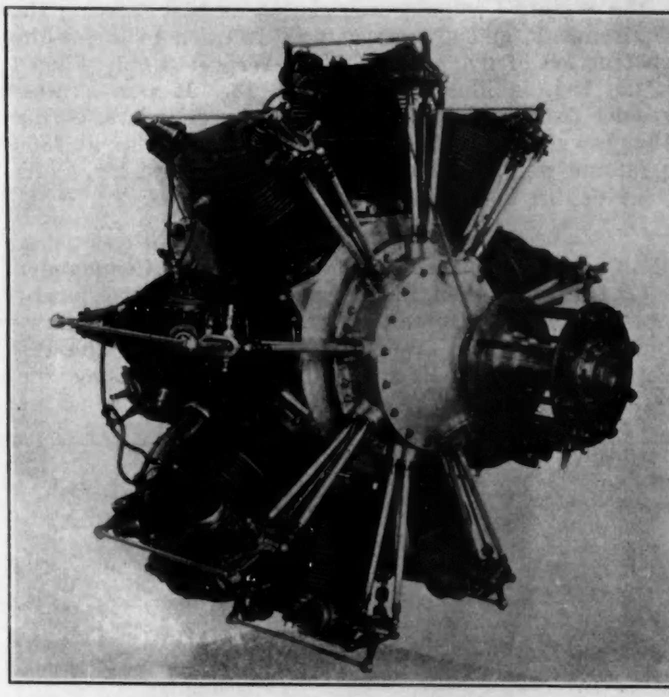

Fig. 14—Wright P-1 Engine, Front View
The Cylinders Are 6 x 6½ In. in Size and Have a Displacement of 1640 Cu. In.

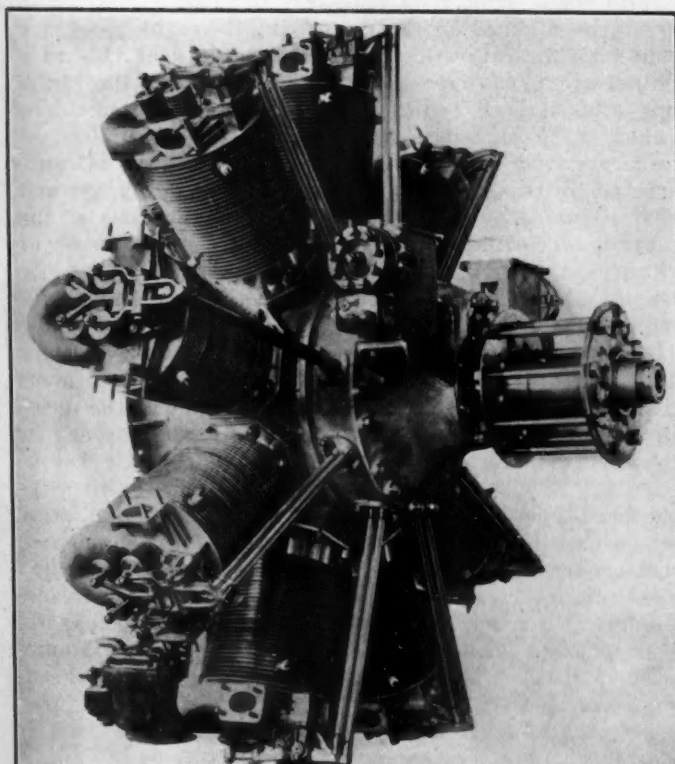

Fig. 13—The Original Wright R-1 Engine, Built in 1920
The First Large Air-Cooled Engine Developed in the United States. It Is of the Nine-Cylinder Fixed-Radial Type with 5⅝ x 6½-In. Cylinders, Giving a Displacement of 1454 Cu. In., Develops 350 Hp. at 1800 R.P.M. and Weighs 880 Lb.

History

The history of air-cooled aviation engines dates from the beginning of flying. It is interesting to note that the early aviators appreciated the dormant advantages of air-cooling. Anzani probably should have the credit for a large part of the early development. It will be remembered that in 1909 Bleriot made the first successful flight across the English Channel with an air-cooled Anzani engine. Before the war, Anzani had built a two-cylinder opposed engine and both three and nine-cylinder radials. The French Gnome and LeRhone rotary air-cooled engines were extensively used for pursuit work in 1914 and 1915. It is reported that the advantages of air-cooled radials were considered so important that the British, in 1919, decided that their entire pursuit program should be centered in them. As a result, the Allen Bennett Croydon radial was in course of development when the armistice was signed. The British throughout the war had in service a number of V-type air-cooled engines designed and built by the Royal Aircraft Factory.

The first successful effort in this Country was the construction of some Gnome and LeRhone engines from French designs. Not until 1918 did any successful American designs appear. At that time, C. L. Lawrance brought out a two-cylinder opposed engine and this was followed by a three-cylinder radial. It will be seen, therefore, that this development parallels in some ways that of Anzani before the war.

Five years ago, the engineering division of the Air Service became convinced of the possibilities of air-cooled radial engines. To stimulate design activity in this field, a design competition was held that was entered by a number of engine builders. The design submitted

by the Wright Company was chosen as best meeting the requirements, and a contract was awarded to it for the construction of five engines. The Wright engine, known as the R-1, is illustrated in Fig. 13. It was a nine-cylinder fixed radial with 5⅝ x 6½-in. cylinders, giving a displacement of 1454 cu. in., developed 350 hp. at 1800 r.p.m. and weighed 880 lb. This was the first large air-cooled engine developed in the United States.

Lawrance Nine-Cylinder Engine

Four years ago, through the foresight of Commander B. G. Leighton, then in charge of engine development for the Navy, the Bureau of Aeronautics gave the Lawrance Company an experimental contract for the development of a small nine-cylinder engine, using the cylinders developed for the three-cylinder engine. This

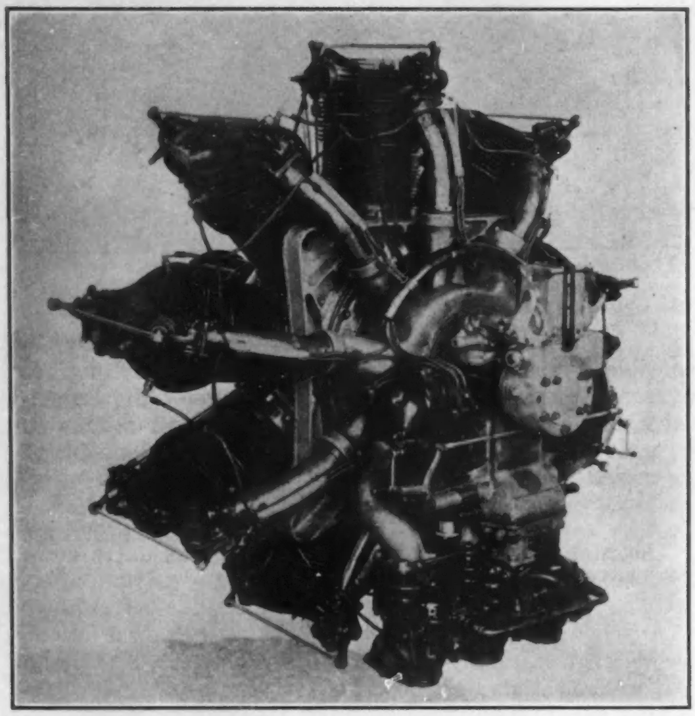

Fig. 15—Wright P-1 Engine, Rear View
The Navy Required That It Be Capable of Replacing the Liberty and That It Have a Maximum Diameter of 45 In. In the Effort To Meet This Requirement, Great Sacrifices Were Made in the Design of the Cylinders

engine was known as the J-1. A number of these engines were put into Naval service, beginning 2 years ago. The J-1 was followed successively by the J-3, J-4 and J-4A, which were developed by the Wright Company after its merger with the Lawrance Company. These engines are now practically standard in the 200-hp. class, several hundred being now in service. To the Navy, therefore, should go the credit of first putting air-cooled engines to work in this Country.

The success of the J-type engine led to the Navy's desire for a larger unit. As a result, the Wright Company developed what is known as the P-1 engine, a front view of which is shown in Fig. 14 and a rear view in Fig. 15. This engine had 6 x 6½-in. cylinders and a displacement of 1640 cu. in. The valves were located in the plane of the crankshaft with the exhaust forward. The Navy required that this engine be capable of replacing the Liberty, and that it have a maximum diameter of 45 in. In an effort to meet the latter requirement, great sacrifices were made in the design of the cylinders.

To begin with, the cylinders were drawn in toward the crankshaft by scalloping the barrels as well as the pistons. The pistons were very short. The ports and valve-guides were necessarily cramped. After several months' effort to make this engine function properly, it was decided to increase the diameter some 3 or 4 in. to eliminate the cut-outs in the cylinders, to provide for somewhat longer pistons and to obtain proper cylinder-ports. The operation of the modified engine showed these changes to be justified. This engine has been superseded by the P-2.

The Radial Type

A question often asked is, Why does the air-cooled aeronautic engine take the radial form? The reason is, that more uniform cooling can readily be secured for each cylinder than with any other type. Originally it was felt that it was necessary to add to the cooling obtained from this disposition of cylinders by rotating the cylinders around the crankshaft. Such engines were called rotary engines and include the Gnome and the LeRhone. This type has been discarded because the rotative speed, and consequently the maximum power of any given engine, was limited by centrifugal force.

It is probable that the radial type will be used for aircraft engines up to 500 hp. at least. Two or more rows of radial cylinders back to back are possible, but are not considered especially promising, on account of the less effective cooling and the added complications, especially of the valve-gear. Wherever more than 500 hp. is required, it is probable that the single or double V-type engine will be used. The Royal Aircraft Factory has already shown this type to be entirely feasible and, in this Country, the Engineering Division has converted a 400-hp. water-cooled Liberty engine into an air-cooled engine.

With the V-type, it is necessary to provide cowling to direct the air-flow to the cylinders; it is not necessary to use a blower for this purpose. Engines of this type are not apt to be lighter per horsepower than the radial type even though counterweights are eliminated. The higher crankshaft-speed possible by the elimination of the master-rod, and therefore the higher power, is counteracted by the added weight of the long crankcase and shaft required by the cylinder spacing. Because of the addition of cowling as well as the increased number of cylinders, the V-type is not so accessible nor so readily dismantled as are radial engines, which are inherently simple from a maintenance standpoint.

In connection with the air-cooled radial type, a number of interesting special problems have presented themselves, one which immediately comes to mind is the question of proper cooling. Strange as it may seem, an air-cooled cylinder is simply a logically designed water-cooled cylinder with the water-jacket replaced with suitable fins properly disposed. This whole subject has been ably covered by S. D. Heron[4] on numerous occasions, and great credit is due him for his able advocacy of the air-cooled engine. Almost any engine having air-cooled cylinders will run if sufficient fuel is used. The measure of an efficient design, however, is that the maximum power shall be obtained with the minimum cylinder-head temperatures that will allow running with a low fuel-consumption. With a poor design, an excess of fuel is required for cooling.

Design

A mistake that has often been made, in connection with air-cooled-cylinder design, is the lack of metal in the cylinder-head. It is just as essential to have ample

[4] See The Journal, April, 1922, p. 231; October, 1922, p. 363; January, 1923, p. 31; July, 1923, p. 16; and October 1925, p. 398.

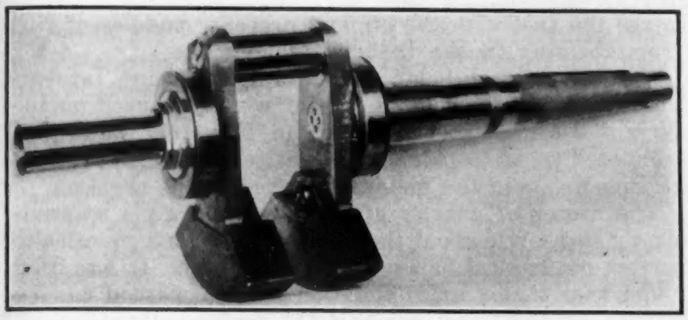

FIG. 16—CRANKSHAFT FOR WRIGHT J-4A ENGINE
The Mechanical Balance of a Radial Engine Involves the Use of Counterweights. These Are Calculated To Balance the Entire Weight of the Connecting-Rod and the Pistons Attached to the Crankpin

material here as in the piston-head. Probably the thing that has retarded most the development of air-cooled cylinders has been the effort to reduce weight; this has resulted in insufficient metal for proper heat-distribution and dissipation. The fact has been overlooked that the ratios of the weight to the horsepower of air and water-cooled engines should not be directly compared; but the weight of the air-cooled engine should be compared with the weight of the water-cooled engine plus its cooling-system. Not only the air-cooled cylinder, but the valves and pistons as well are similar to water-cooled cylinders of good design.

Mercury and salt-filled exhaust-valves are sometimes used but are not always essential. So far, the four-valve type of cylinder has not been extensively used in this Country. The cooling of this type obviously presents a considerably more difficult problem. Modern practice uses a steel barrel in conjunction with an aluminum head, two valves per cylinder, both the exhaust and the inlet

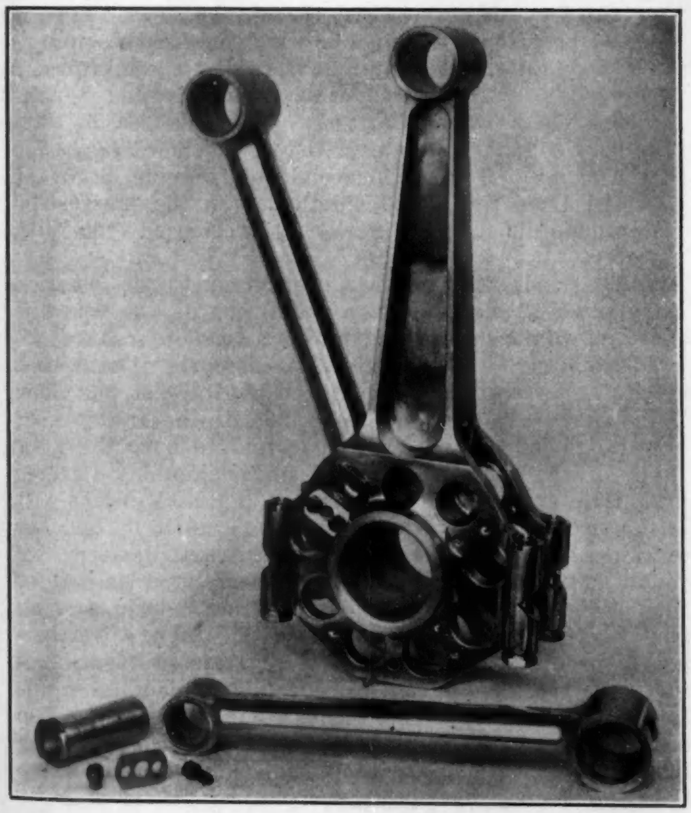

FIG. 17—THE WRIGHT R-1200 CONNECTING-ROD
To Equalize the Compression Ratio of the Various Cylinders, It Is Necessary To Vary the Knuckle-Pin Centers with Respect to the Crankpin, or To Use Different Heights of the Cylinder-Pads

ports being toward the rear, with the valves located in a plane at right-angles to the crankshaft and operated by push-rods and rocker-arms.

VALVE-GEAR

The valve-gear, owing to the disposition of the cylinders, is somewhat different from that customary in motor-car work. To begin with, in place of camshafts, two sets of four equally spaced cams, one set for the inlet and one for the exhaust-valves, are carried on a cam-drum. This is concentrically arranged around the crankshaft and, in the case of the nine-cylinder engine,

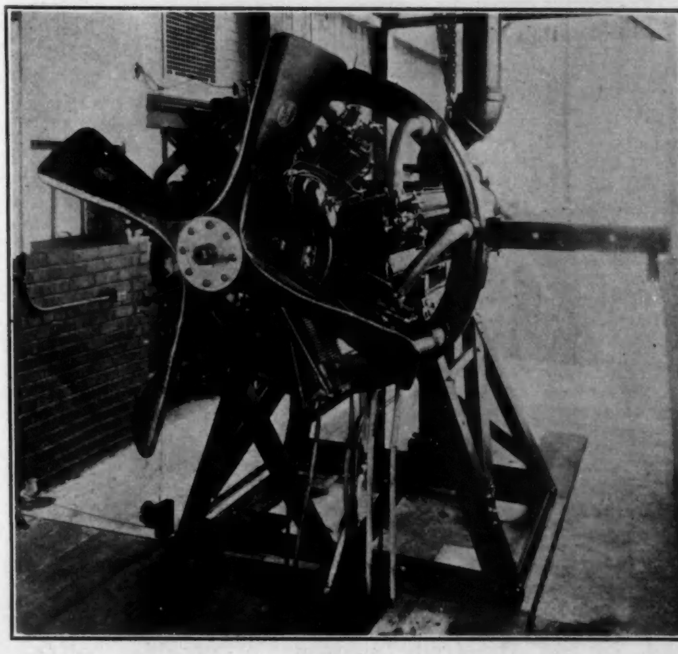

FIG. 18—WRIGHT J-4 ENGINE MOUNTED ON REACTION TORQUE STAND
This Is Cheaper than the Electric Dynamometer and Can Be Made Fairly Quiet by Proper Air-Ducts and by Collecting the Exhaust and Introducing Water

is driven by suitable gearing at one-eighth the crankshaft speed in a direction opposite to that of the crankshaft.

Modern valve-gear, for the most part, is enclosed both to protect it from water and dirt and to retain the lubricating oil. In most modern designs, some means of compensation is used so that the timing is practically unaltered from cold to hot. With the ordinary rocker and push-rod construction, the tappet clearance increases as the cylinder elongates with heat. As a result, the tappet clearance may run as high as 0.07 in. when hot. A system of hydraulic operation has been developed by Mr. Noble that eliminates the push-rod and the rocker. The valves are operated by individual oil-pumps that displace liquid through a tube and consequently open each valve by the pressure of this medium against proper pistons bearing upon the valve-stem.

Another problem associated with radial engines is that of lubrication. As is so often the case in engineering, the task that looks the hardest is the easiest; the question of preventing over-lubrication of the inverted cylinders is readily taken care of. For the most part, scraper-rings are used on the bottom of the pistons and, to prevent oil from overflowing into the lower cylinders, the cylinder barrels are extended into the crankcase and a sump is provided, of sufficient capacity to hold all the oil that might drain from the inside of the case whenever the engine is stopped.

The Bristol Engine

Two British engines use rather unique crankpin lubricating-systems of their own. The Bristol, formerly the Cosmos, a nine-cylinder radial, has spouts attached to and surrounding the crankpin for collecting oil thrown off from the big-end bearing. These spouts travel in circular troughs attached to the inside of the crankcase. With this arrangement the surplus oil is carried away from the cylinders, which are lubricated simply by the oil thrown from the knuckle-pins.

The Jaguar, a 14-cylinder two-row British engine made by the Armstrong Siddeley Co., provides for the lubrication of the big end by carrying oil to the center of the crankpin under pressure. From there it flows outwardly along the pin to a groove cut at either end of the pin in the big-end bearing that registers with return-holes in the crankpin. The return-holes are connected to a suction-pump so that the surplus oil which would otherwise be thrown from the big end is carried back to the storage-tank. Here, again, the cylinders receive oil from the knuckle-pins only. In this Country we have not found it necessary to use so elaborate arrangements to prevent over-oiling. As a matter of fact, it has been found more desirable to provide proper seals on the pistons and to throw off an adequate amount of lubricating-oil from the crankpin to reduce the temperature of the parts inside the crankcase.

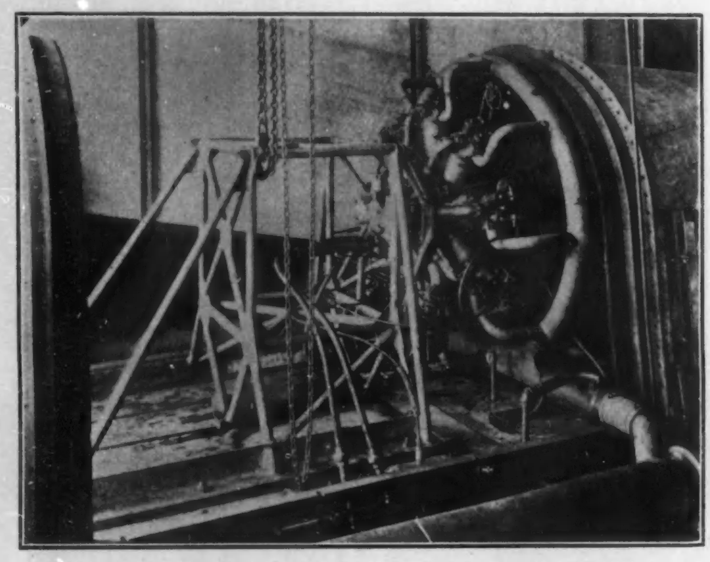

Fig. 19—Wright Production Electric-Dynamometer Stand
This Method Requires That the Engine Be Cooled by Air Having a Minimum Velocity of Approximately 80 M.P.H.

Various systems of gas distribution have been used. So far, the most satisfactory has been three separate three-cylinder induction-systems, consisting of circular manifolds with cylinder leads 120 deg. apart, each provided with its own carbureter. If a single inlet-valve becomes inoperative, only three of the nine cylinders are affected. This system has the disadvantage of considerable weight and complication. A modification has been used by the Wright Company in which the three manifolds are connected to a single double-barrel carbureter.

Rotary Distributing-System

A third system of considerable promise is the rotary distributing-system, in which a single carbureter is used in conjunction with a small blower from which the gas is taken tangentially to the various cylinders. The blower not only distributes the gas uniformly, but thoroughly mixes the fuel with the air and prevents puddles of fuel from forming in the induction-system.

The mechanical balance of a radial engine involves the use of counterweights, one of which, as used on the Wright J-4A engine, is shown in Fig. 16. These are calculated so as to balance the entire weight of the connecting-rods and the pistons attached to the crankpin.

The center of gravity of this system travels approximately in a circle about the crankshaft so that practically perfect mechanical balance can be secured. It has been found that a fair approximation to this method can be secured by balancing one-half the reciprocating and all the rotating weight, considering it all to be on the crankpin. With the longer strokes, the travel of the center of gravity becomes an ellipse, so that it is necessary to determine upon the best circle and to make an approximation of the balance. The concentration of all the connecting-rod weights upon one crankpin results in large counterweights; for example, a 1650-cu. in. engine may require counterweights that weigh approximately 60 lb.

Connecting Rods

The design of the master connecting-rod, Fig. 17, involves a study of knuckle-pin travel that is particularly interesting. The knuckle-pins adjacent to the master-rod, which is usually put into the vertical or No. 1 cylinder, travel in nearly circular paths, while the pins for rods Nos. 5 and 6, which are at the bottom, have an ellipselike motion, with the long axis nearly at right-angles to the cylinder center-line and considerably greater than the stroke.

To equalize the compression ratio of the various cylinders, it is necessary either to vary the knuckle-pin centers with respect to the crankpin, or to use different heights of cylinder-pads. As the motion of certain knuckle-pins becomes more and more elliptical the farther removed they are from the crankpin, an effort is made to keep the crankpin small and the knuckle-pins as close to the center of the pin as possible. The master-rod necessarily receives considerable bending due to the forces applied by the link-rods. For this reason it is necessary to make the master-rod of considerable section in the shank. Due to this condition, trouble might be expected from the added sidethrust on the master-rod piston. No difficulty ordinarily is experienced from this, however.

Considerable attention has been given to the question of the over-all diameter of a radial engine. It was felt that this dimension should be kept small to reduce the head-resistance of the engine, in comparison with that of a similar-powered water-cooled engine. It has been found, however, that the resistance of the radiator of a water-cooled engine, as well as that due to the poor shape of the fuselage, resulted in considerably greater drag than that of the cylinders of a radial engine. It is the same old story that something cannot be had for nothing. In an effort to meet an arbitrary diameter, we found that pistons could be made too short, resulting in their trying to turn over in the cylinders and scoring badly, and that the valve-guides and springs were so poorly proportioned that they were entirely unsatisfactory. Proper port areas, moreover, could not be maintained. By adding a few inches to the diameter, these conditions can be entirely corrected and the duration increased many times without noticeable detriment to the performance of the airplane.

Testing

Testing has its particular problems. Two methods are used, namely, the reaction-torque stand with a club

and the electric-dynamometer. The torque-stand method shown in Fig. 18 is the cheapest and can be made fairly quiet by proper air-ducts and by collecting the exhaust and introducing water. Power measurements from this equipment are not especially accurate but are sufficiently good for production testing. The electric-dynamometer method, Fig. 19, requires that the engine be cooled by air having a minimum velocity of approximately 80 m.p.h. In this case, the engine must be mounted in a tunnel that is connected to a large blower. Such equipment is expensive but very accurate, and is, therefore, desirable for research work.

Conclusions

In reviewing the progress to date and the possible development in the future, certain essentials must be kept in mind. Dependability cannot be sacrificed at any cost, particularly in commercial aviation. As experience accumulates, dependability will increase. Most rapid progress in this direction can be made by simplification rather than complication.

The proper size of powerplant is essential to mechanical operation. It should be borne in mind that high engine-efficiency can be entirely nullified by poor propeller-efficiency.

The importance of the minimum total powerplant weight for any given service must not be overlooked. Any powerplant-weight reduction is reflected in increased pay-load for commercial operation, or in improved performance for military service. All the items that are a part of the total powerplant weight are equally important from a weight standpoint, but fuel economy is undoubtedly of the greatest importance for commercial operation, particularly at cruising-speeds. Intelligent development of all the essentials that have been discussed will be of great importance in the establishment of commercial aviation.

THE NEW ASIA

JAPAN accepted and adopted Western civilization; China, until lately, resisted it; and the tropical peoples of Malaya, India, the Philippines and the Dutch East Indies succumbed to it after a brief struggle.

Lacking in coal, Japan has made remarkable progress in hydro-electric development; having no iron ore, 80 per cent of China's iron resources have come under Japanese control. Home production of the wool and raw cotton needed in Japan's new textile industry being impossible, Australia and the United States have become steady sources of supply for these.

The abundance of copper in Japan and the presence of plentiful hydro-electric energy have made the electrical industry one of the most promising developments, while cheap and ample sulphur and wood have formed the basis of an encouraging match industry. The glass and paper industries were also favored by a good supply of raw material.

China's foreign trade has continued to increase. Year by year the value of shipments and receipts has mounted. "Sales service" is the keynote of further American trade growth in the Indian field. American manufacturers have gone as far as they can reasonably expect on their present limited agency arrangements, which are mostly in the hands of British or native firms. Those American houses which have been enterprising enough to send direct representatives, either to cooperate with the local agent or to solicit orders directly, have found not only that "service" of the accepted American brand is an unknown quantity but that when made available it is keenly appreciated by the Indian customer. There are large amounts of capital in the interior of India, mostly in bullion or jewels; and as soon as there are evidences of lasting political stability, such as now seems practically assured, this capital will seek employment in expanding the numerous industrial and agricultural activities which already have proved so profitable. Demands for American machinery and implements will then come from all parts of India, but unless we are equipped and on the ground to handle the business it will go elsewhere. American motor-cars are likely to be in great demand. In 1920 India was, next to Great Britain, our largest market for passenger cars.

Many changes are occurring in the economic life of the tropical and semi-tropical peoples of British Malaya, Siam, French Indo-China, Dutch East Indies and the Philippines. The economic pall that has hung over this region since 1920, when producers faced the necessity of continuing their activities even with world market prices for their products below the cost of production, is now being lifted by steadily improving world demands for rubber, tin, cocoanut oil, gums, tapioca, spices, tea and coffee at prices which offer a reasonable profit to the producer. This has not been brought about without resort to artificial export restrictions, but these restrictions did not dispose of heavy accumulated stocks and would have been of little avail without increasing consumption demands, particularly in the United States.

For years the cost of doing business in the Orient has been greatly increased by the multiplicity of intermediaries. An American product destined for a consumer in Java would be ordered through a Dutch house in Batavia with a head office in Rotterdam, which in turn would place the order with an American manufacturer through its New York agents. When the American goods reached the consumer in Java the laid-down price bore the burden of all this roundaboutness. The movement to buy direct is being fostered by the dealer in Java, himself. He is welcoming direct representatives of American manufacturers and encouraging them to open direct distributing agencies.

We sell the Far East only half as much as we buy from it. While America is one of the principal outlets for the products of the Orient and our purchases of its raw products increase year by year, our sales remain stationary. Without the American market for rubber and tin, British Malaya would languish in poverty; and a withdrawal of America's demand for Indian jute, manganese and shellac would be felt most keenly.

Almost half of Japan's total export trade is raw silk—and America takes 80 per cent of it. We supply Japan with most of its raw cotton in return; but our share in the import trade of British Malaya, the Dutch East Indies, India and other tropical countries is negligible.

The gain (12 per cent) in our imports from the Far East during the fiscal year ending June 30, 1925, is entirely due to industrial activity in the United States and expanded markets for Oriental products in our industries.

A somewhat lower price-level during the fiscal year 1925, bad economic conditions in Japan, and disturbed political conditions in China account for the decline in our export trade to the Orient.

The Oriental trade balance against the United States was $172,000,000 during the 1922 fiscal year. In 1925 it had grown to $489,000,000, our shipments to the Orient amounting to 56 per cent of our imports from the same source this year.

The Orient is rapidly becoming one of the leading sources of raw materials for our factories, and the industrial development in Japan, India and to a lesser extent in China, is opening up wider markets for our products. Along with this development new methods of doing business, involving more direct relations between our manufacturers and their Oriental customers, are being rapidly introduced.—F. R. Eldridge in *Commerce Reports*.

CONTINUOUS PRODUCTION

NO authority can be discovered to justify the use of the words "mass production" as applied to engineering manufacture. The term is probably journalese derived from a German military phrase, whereas the processes referred to hereafter are not aimed at attacking enormous quantities, but are an endeavor to secure continuous flow.

Continuous production is, of course, no new thing. It has been practised for many years in the food, soap, textile, newspaper and other industries. It is, however, comparatively new to the engineering industry. In the automobile industry many hundreds of different parts have to march together in their processing, and this entirely separates the automobile engineer from the manufacturers already mentioned.

In continuous production the example of the flour miller and the soap boiler must be borne in mind. The ideal of continuous flow must be present from the design and raw material stages up to and even beyond the sales stage. The post-sales stage does not affect the industries previously named, but it is a serious matter for the car builder, for spare-parts requirements affect the flow as to quantity, and, where many modifications are made, the resetting of machines will seriously affect both plant and output. This applies, of course, to the medium-sized British plants and not to the great American firms, who can set up special departments for machining spare parts.

Machine shops were, originally, general engineering shops, and, for convenience, similar machine-tools were grouped together, and from this grew the idea that foremen could best manage shops in which the types of tools were similar. This persisted even when engineering shops were placed on a repetition basis, but, with the advent of the automobile, it became evident that this arrangement involved considerable transport, and when, as frequently was the case, every part at each operation was taken to a central view room, the old arrangement became unwieldy. So machines were arranged for the work to flow naturally from stage to stage, and inspectors were placed at intervals in the shop. The foremen became much more versatile, and only certain complicated machines, like gear cutters and automatics, were grouped. Now, when the layout calls for it, even these can be found "in line" with the other plant. The conveyor system is now making itself felt, but this is only feasible on anything like a large scale, on large outputs where a settled manufacturing policy is in force. In large-scale manufacture the tendency is to group all of one operation in one shop, so that the shops rather than the machines are in line, but this does not suit the smaller productions and the Morris Engines' methods aim at putting down "continuous machines" to look after a certain output and putting down parallel lines as more production is required.

The Morris Engines took over the Gosford Street works from Hotchkiss et Cie, in January, 1923; it was then a very efficient organization, producing 300 engines per week; by December, 1924, an output of 1200 engines per week had been achieved. The productive area is now 18,787 sq. yd.; the electric current used is equivalent to 1520 hp.; there are 2200 employes and 768 machines. To illustrate how quantity production cheapens a unit, it may be stated that on an output of 100 per week, it took four men occupying 53.0 sq. yd. in area and using 2.1 machines and 3.5 hp. to produce one engine and gearbox. On an output of 1200 per week, 1.83 men occupying 15.60 sq. yd. in area and using 0.64 machines and 1.27 hp., produced the same articles, the time in both cases being the same. This, it should be said, was brought about without any noticeable alteration in design. It will, of course, be asked when the reducing process will stop. I doubt whether any satisfactory answer can be given to that question. Obviously, the lowest level of machine-shop costs will be approached when every machine is fully occupied on one operation, but perfect machine-balance can never be obtained, because as soon as balance is obtained in one direction, an improvement is made in either machine or equipment, so that, within my knowledge, which is confined to this country, finality is a long way off. The nearer the approach is made to the best economic conditions of the plant, the less the reductions. An efficiency of 100 per cent is never reached. The machine shop is, of course, only one element; larger operations permit extensions back toward raw materials, and so produce the vertical trust position of some of the great companies in the United States of America.—From a paper by F. G. Woolard, of Morris Engines, Ltd., Coventry, England; presented before the Institution of Automobile Engineers.

INTERNATIONAL STANDARDIZATION

THE importance of standardization in relation to future industrial development can hardly be over-estimated. Our industries within comparatively recent times have multiplied very rapidly, and not sufficient attention has been paid to the economies that are possible in simplifying types, designs and dimensions of commodities, and in standardizing materials and practices. In its essentials standardization is simply a process of selection of types, designs, materials or practices that in the course of time have thoroughly proved their value to the general community, a sort of "survival of the fittest," and a concentration upon these types and materials in production and use in the interests of greatest efficiency. Only recently have the comparatively chaotic conditions in which industry has found itself in this respect, due to its very rapid development, awakened us to the necessity of applying the principles of standardization to problems of production, distribution and consumption. If these principles are properly applied, little apprehension need be felt that standardization will weaken the incentive to originate, to invent and to apply in the industries of the world desirable new types, new materials and new processes.

Standards are accused of "fixing" practice in such a way as to retard desirable progress in industrial development. The fallacy of this criticism is evident as soon as one appreciates that standards simply express the results of experience in the successful use of commodities and really conserve our time and energy for the study of new developments that otherwise would be occupied with routine matters. Changing experience as influenced by new developments is in due course reflected in our standards. The existence of a long-established standard specification for a given material that is widely used for a given purpose does not prevent some one from developing a new material that is more satisfactory for that purpose. The extent to which the new material will replace the old is a matter essentially of economic considerations, such as price, dependability of supply and the like. When conditions in the industry warrant it, a standard specification is developed to govern the purchase of the new material and is used side by side with the older specification so long as the trade continues to use the older material to any appreciable extent. Instances of this kind are constantly occurring.—From a paper by C. L. Warwick, secretary-treasurer of American Society for Testing Materials presented at First Pan-American Standardization Conference.

THE TECHNICAL SOCIETY AND THE ENGINEER

As mentioned on p. 412 of this issue of THE JOURNAL, the Institution of Automobile Engineers has rendered a distinct service by issuing recently a summary statement on the Value of the Institution to Its Graduate Members. It presents in substance the views of the Graduates themselves, who hold membership in the Institution corresponding in large part to the Junior membership of the Society of Automotive Engineers. It is mostly the "apprentice", in English parlance, that is discussed in this statement. The pamphlet covers comprehensively the various human, social, industrial, business and technical phases that inexorably demand consideration in the adequate training and development of an engineer who hopes to be prominent, successful or effective in the automotive field or any field of large scope. The following excerpts from this admirable article have been made for the perusal of the members of the Society.

The Institution of Automobile Engineers is a fingerpost from the workshop to the college. It helps to carry the interest of the apprentice beyond the mere mechanical operations on a certain piece to a consideration of the reasons that have led to the selection of the precise form and dimensions of that piece, and it encourages him to analyze those reasons for himself in such a way that he can not only satisfy himself as to their soundness or otherwise, but demonstrate his conclusions to others.

This is brought about primarily by the inducements that the Institution offers to Graduates—that is, members of the Institution who are under 25 years of age—to read papers before their fellow Graduates and to take part in the discussion on papers read by others.

Beyond question, in the preparation of a paper the writer must make himself thoroughly well acquainted with every aspect of the subject of which he proposes to treat, since he must not only be able to write comprehensively about it, but the information he gives must be accurate and uptodate; and he must also be able to answer at short notice the questions raised in the discussion.

Probably no item in the normal training of an engineer receives less attention than that of self-expression, and yet a technical report may lose the major portion of its significance, not because the writer is insufficiently acquainted with his subject, but because he has not the art of self-expression and cannot put his ideas forward coherently and in good English. Again, the ability to express lucidly the reason for any particular alteration in design, or to explain any technical objection to the adoption of some accessory, will often save friction between the works and the sales department, or between the sales department and a dissatisfied customer.

The discussion affords opportunities for a Graduate to judge himself by the ability of others of his own age and so provide to those who find themselves falling behind an incentive to improve themselves. Thus the standard of the junior members as a whole is raised and their value to the industry increased.

Many members of the Institution owe their position today largely to the prominent part they have played in their younger days in the work of the Graduates' Centers. It is a Graduate's own fault if he does not take full advantage of the opportunities offered to him by making earnest efforts not only to attend regularly but to speak frequently at the meetings held in his locality.

The value of breadth of outlook can hardly be overestimated, and a conception of the difficulties of other people such as can be obtained at the meetings must tend greatly to harmony between the various departments of any works. Manufacturing methods always have to be adapted to the particular product to be handled, to the quantities involved and to the degree of accuracy required.

Another way in which the Institution helps to widen the outlook of those who join its ranks is by the visits to works, which are arranged by the various Centers so that Graduates may have the opportunity of seeing methods of manufacture and works layout differing from those with which they are ordinarily in contact. This is particularly valuable in the case of the manufacture of accessories and materials, most of which are not produced by the maker of the car, but are left to the specialist. If it were not for these visits the budding automobile engineer would have little opportunity of acquainting himself with the production of these parts, and it is very necessary that, as a future user thereof, he should know enough about the difficulties and limitations of their manufacture to keep clear of ridiculous or impossible specifications in his designs.

Many young men with ambitions that lead them to spare no pains to improve their technical knowledge pay very little attention to the social and public sides of their education, not recognizing that many social duties are bound to fall to the lot of a man when he has finally achieved distinction. One of the most important results of membership of the Institution, but one that can hardly be assigned a direct value, is enthusiasm. This is probably the greatest of all contributory factors to success. Without enthusiasm no man can ever get far. Technical learning is assured to those who are making really good use of the technical institutions which it is the duty of every apprentice to attend. It is in less obvious directions that membership of the Institution is able to play so great a part in the life of any Graduate who has sufficient energy to make the necessary effort.

NATURAL-GAS GASOLINE

The production of raw or unblended natural-gas gasoline in the United States in 1924 amounted to 933,861,000 gal., an increase of 117,635,000 gal. over the output in 1923, according to a statement just issued by the Bureau of Mines. The figure is based on reports by 457 producers, operating 1096 plants in 13 States, made to the United States Geological Survey before the transfer of the division of mineral resources to the Bureau of Mines. Of this total, 89,495,000 gal. was run into crude petroleum pipe-lines and mixed with the oil that goes to refineries to be distilled, and the remaining output of raw natural-gas gasoline, excepting losses and the relatively small quantity utilized in the raw state, was blended for use as motor fuel. Increased production in 1924 was reported in all of the States, excepting West Virginia, Ohio and Kentucky, in which small losses were recorded, the greatest gain over the output in 1923 being in California, where the increase was 34 per cent. The output of the three leading States—Oklahoma, California and Texas—amounted to 77 per cent of the total production of the Country. The dominating position of the industry in the States west of the Mississippi River is shown by the fact that 89 per cent of the total output of natural-gas gasoline in the United States in 1924 was produced in that area.—*Economic World.*

AIRPLANE-ENGINE GENERATOR-PROBLEMS[1]

BUILT to provide the maximum output for a given weight, component parts of airplane engines are light yet strong; but that engine explosions can cause crankshaft torsional displacements is evident. The propeller is the flywheel; since variations in its number of revolutions are slight compared with those of the crankshaft, it can be considered as revolving at constant velocity, but crankshaft "whips" are transmitted to all accessories. When the cylinder farthest from the propeller fires, the maximum torsional deflection occurs if the accessories' drive is at the crankcase-end farthest from the propeller, which is true for most airplane engines.

Regarding generator-drive pulsations, the generator driveshaft is geared directly to the non-propeller end of the Liberty-12-engine crankshaft, the splined generator shaft has a slip-fit into an internal spline of the generator drive and the generator makes one and one-half revolutions for each one of the crankshaft; four explosions occur for each generator revolution, causing four distinct "whips" and the problem of a dependable generator drive increases when a larger generator is installed. Increasing armature size increases generator size and armature flywheel-effect and, as flywheel-effect becomes greater, so do the stresses due to variation in angular velocity.

Early Liberty-12 engine history showed generator-armature failure to be due frequently to a shifting of armature punchings on the shaft, a difficulty overcome later by providing the punchings with an internal spline and slipping them over a splined generator shaft, but the stresses remained. The armature then was subject to a 13-deg. whip; tests on 1-L generators of 15-volt and 10-amp. rating showed a 10-deg. whip at least and later failures proved that well over a 15-deg. deflection existed, the springs being deflected enough to gouge the housing.

Stresses

A friction-clutch drive was incorporated in the first 25-amp. generator built, it being expected to slip during severe whips and thus protect the generator; but clutch setting decreased with wear of the friction surfaces and the small driving shafts broke, which caused the incorporation of a spring drive that permitted a strong driving shaft equipped with four sets of cantilever springs that absorbed angular vibrations. Although at first thought satisfactory, failures caused changes later in the cantilever-spring construction from three 0.035-in. to eighteen 0.016-in. springs arranged to drag on the housing rather than gouge it. The heavy springs broke in ½ hr., but similar tests on the thin springs developed no failure in 90 hr. Armature weights are 3 lb. for the 7-amp., 10 lb. for the 25-amp. and 12½ lb. for the 50-amp. sizes. Armature-mass flywheel-energy is, at 2250 r.p.m., about 10 ft-lb. for the 7-amp., 63 ft-lb. for the 25-amp. and 110 ft-lb. for the 50-amp. generator. At an assured 5-deg angular-variation between the armature and the generator drive, the spring drive must absorb 7½ ft-lb. of energy for the 25-amp. and 13 ft-lb. for the 50-amp. generator, the force being applied at a radius of 1½ in.

Aims of Generator Design

A generator to withstand 500 hr. of service on a Liberty-12 engine is desired; at present, 100-lb. service would be highly desirable as such a generator would need care only during engine overhaul, but its weight must reach the minimum and this complicates the problem. The protective coupling must be light and compact, and the present design using victrola-spring material shows promise. Constant angular-velocity of the armature permitted by the coupling while it absorbs the variations of the pulsating drive is what is wanted, and the present thin-spring drive constitutes an approach to the desired constant-velocity condition.

Coupling and Drive-Deflection Tests

The advantages of the rubber-cushion drive are that few parts can break and these can be readily repaired; the disadvantage due to rubber-block wear is not considered vital and the test of this experimental drive now being conducted should prove or disprove its worth definitely. After 50 hr. of engine operation, in the torsion leaf-spring-drive test, a locking pin was worn but did not fail; a flat key was substituted and the test was continued. This drive increases the generator diameter slightly but allows a shorter generator.

Generator-drive-deflection measurement by locating a Wheatstone-Bridge net work at the points where it is desired to determine the amount of deflection, with its indicating portion connected to an oscillograph that will record deflections and thus show the angular variation when compared with a calibrating oscillogram taken under conditions of no deflection, is being planned. A calibrating oscillogram possibly may be obviated by careful location of the Wheatstone-Bridge elements; the requirement for no calibration being that at some unstressed engine-position the indicators shall point to zero. With this condition attained, all oscillograms taken under stressed conditions actually will show the angular variation between the test locations.

[1] Abstract of an address at McCook Field, Dayton, Ohio, made to representatives of the American Society of Mechanical Engineers and members of the Dayton Section. Mr. Allen is assistant chief of electrical branch of the engineering division, Air Service, McCook Field, Dayton, Ohio.

BRITISH TO CONDUCT HIGHWAY RESEARCH

THE British Ministry of Transport has been authorized recently by Parliament to undertake a program of highway research. To avoid duplication of effort and to secure the advantage of American experience, the Chief Engineer of the Roads Department, Col. C. H. Bressey, has asked for all possible data derived from tests in this Country.

Sir Henry Maybury, director-general of the Roads Department, paid particular attention to the research work that is being conducted by the Bureau of Public Roads at the Arlington Experimental Farm when he was in the City of Washington recently. The British Department apparently intends to take full advantage of the authority granted it by Parliament and prosecute a program of highway research similar to that which is being carried on in this Country by the Bureau of Public Roads and other agencies. They hope to avoid overlapping on the work that has been done here, and apparently they are very anxious to cooperate with Americans in every possible way.

Reports of research conducted in this Country have been forwarded to Colonel Bressey by the Highway Research Board, the Bureau of Public Roads and other agencies, and the Board will keep in close touch with the work that is done by the British department as its program develops.—*Highway Research News.*

Applicants *for* Membership

The applications for membership received between Sept. 15 and Oct. 15, 1925, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ADAMS, BURNHAM, experimental engineer, Wright Aeronautical Corporation, *Paterson, N. J.*

ALTORFER, A. W., vice-president and chief engineer, Altorfer Bros. Co., *Peoria, Ill.*

AUSTIN, CHARLES EARL, production manager, United Motors Products Co., *Grand Rapids, Mich.*

BARROWS, BURTON M., vice-president and treasurer, McFarlan Motor Corporation, *Connersville, Ind.*

BELANGER, J., body tool engineer, American Body Co., *Buffalo.*

BEST, EDWARD V., machine designer, A. C. Spark Plug Co., *Flint, Mich.*

BRUNN, HERMANN A., president, Brunn & Co., *Buffalo.*

BUCK, ARTHUR V., superintendent of repairs, Hahn Motor Truck Co., *Hamburg, Pa.*

BYINGTON, R. I., district manager, Cedar Rapids Engineering Co., *Cedar Rapids, Iowa.*

CANALI, FREDERIC, mechanical engineer, Chevrolet Motor Co., *Detroit.*

CAPSEY, B. H., service manager, Willys-Overland Co., Ltd., *Toronto, Ont., Canada.*

CHOATE, CHARLES ALLEN, supervisor of motor engineering department, Provincial Institute of Technology & Art, *Calgary, Alta., Canada.*

CHURGAY, L. A., plant equipment engineer, Chrysler Corporation, *Highland Park, Detroit.*

CLARK, NORMAN B., draftsman, Chrysler Corporation, *Highland Park, Detroit.*

COLE, PHILIP G., president, A. Schrader's Son, Inc., *Brooklyn, N. Y.*

CONNIFF, JOSEPH, superintendent of equipment, People's Motorbus Co. of St. Louis, *St. Louis.*

COOK, WILLIAM P., laboratory assistant, White Motor Co., *Cleveland.*

COSTIGAN, WESLEY S., works manager, Reynolds Spring Co., *Jackson, Mich.*

CROSBY, GEORGE A., designing engineer, Brook Steam Motors, Ltd., *Stratford, Ont., Canada.*

DAUM, CARL C., draftsman, Maccar Truck Co., *Scranton, Pa.*

DEBBINK, HENRY L., superintendent of gasoline vehicles, Milwaukee Electric Railway & Light Co., *Milwaukee.*

DEMUTH, ARMIN, consulting engineer, *New York City.*

DIFFENBAUGH, ROY T., mechanical engineer, International Harvester Co., *Chicago.*

DINGLEY, BERT, service manager, Nordyke & Marmon Co., *Indianapolis.*

DINSLAGE, FRANZ, manager, Deutsche Kraftfahrzeugwerke A. G., *Spandau, Germany.*

DONOVAN, TIMOTHY P., designer and engineer, Board of Transportation, *New York City.*

EHRICH, E. H., master mechanic, Sparks-Withington Co., *Jackson, Mich.*

ELLIS, EMMETT S., tool engineer, Motor Wheel Corporation, *Lansing, Mich.*

GEIGER, D. HEBER, sales engineer, Parish Mfg. Corporation, *Reading, Pa.*

GRAWEY, WILLIAM F., owner and manager, Peoria Auto Parts Co., *Peoria, Ill.*

GRIMSHAW, ROBERT S., body designer and color artist, Deitrich, Inc., division of Murray Body Co., *Detroit.*

GWYN, LEWIS R., JR., assistant superintendent American Railway Express Co., *Brooklyn, N. Y.*

HAIG, FREDERIC WILLIAM, automotive engineer, Vacuum Oil Co. Proprietary, Ltd., *Melbourne, Australia.*

HEMPY, W. J., designing engineer, Hempy-Cooper Mfg. Co., *Kansas City, Mo.*

HENDERSON, PAUL, general manager, National Air Transport, Inc., *City of Washington.*

HENRY, JAMES S., engineer, Commerce Motor Truck Co., *Ypsilanti, Mich.*

HINE, EDWARD B., lubrication engineer, Vacuum Oil Co., *Pittsburgh.*

HIRSCHHAUTER, E. E., chief tool designer, Advance-Rumely Co., *La Porte, Ind.*

HOAG, WILLIAM M., specification engineer, Ford Motor Co., *Detroit.*

HUNGERFORD, I. A., distribution manager, Borden's Farm Products Co., Inc., *New York City.*

HYLTON, C. H., technical assistant to sales department, Karrier Motors, Ltd., *Huddersfield, York, England.*

JOHNSON, HAROLD L., draftsman, Sheldon Axle & Spring Co., *Wilkes-Barre, Pa.*

JOHNSON, RAYMOND H., shop foreman, Blue Bus Line Co., *Tampa, Fla.*

JOHNSON, T. RAY, vice-president, Hannum Mfg. Co., *Milwaukee.*

KNEIP, LIEUT. J. B., Navy Department, *City of Washington.*

KOIDZUKA, SCHICHIBEI, service manager, Shibaura Factory, Yanase Automobile Co., *Tokyo, Japan.*

KREIS, O. C., engineer, Continental Motors Corporation, *Detroit.*

KRIETER, HARRY R., student, University of Michigan, *Ann Arbor, Mich.*

MCCLELLAND, S. S., manufacturer of automobile accessories, S. S. McClelland, *White Plains, N. Y.*

MCCUNE, JOSEPH C., district engineer, Westinghouse Air Brake Co., *New York City.*

MACFARLAND, WILLIAM E., department of exhibits, Sesqui-Centennial International Exposition Association, *Philadelphia.*

MEEKER, DAVID A., research engineer, General Motors Corporation, *Detroit.*

MUKERJEE, MRITUNJAY, draftsman, Hudson Motor Car Co., *Detroit.*

NOORDUYN, R. B. C., vice-president, Fokker Aircraft Corporation, *New York City;* treasurer, Atlantic Aircraft Corporation, Hasbrouck Heights, N. J.

OBERLANDER, M. A., wiring supplies sales manager, Western Electric Co., New York City.

OSBORN, PAUL VICTOR, control manager, Continental Motors Corporation, *Detroit.*

PELAN, JOHN S., charge of electrical experimental laboratory, Mack International Motor Truck Co., *Long Island City, N. Y.*

PIASECKI, JOSEPH A., junior draftsman, Zaremba Co., *Buffalo.*

POPE, EDWARD J., sales promotion department, Ferodo & Asbestos, Inc., *New Brunswick, N. J.*

RAISCH, CHARLES F., mechanical engineer, Cruban Machine & Steel Corporation, *New York City.*

RAVIOLO, JOHN B., automotive designer, *Newark, N. J.*

RIEHL, WILLIS A., factory superintendent, Brooks Steam Motors, Ltd., *Stratford, Ont., Canada.*

ROBERTSON, BURTON J., assistant professor of gas engineering, University of Minnesota, *Minneapolis.*

SCHIEFER, FRANK, chief engineer, Charles Hvass & Co., *New York City.*

SCHUNCK, FRED E., storekeeper, Milwaukee Electric Railway & Light Co., *Milwaukee.*

SCOFIELD, CARL R., checker, Burroughs Adding Machine Co., *Detroit.*

SHERRICK, EVERETT B., draftsman, Cadillac Motor Co., *Detroit.*

SHIELDS, J. W., engineer, truck and motorbus tire division, Firestone Tire & Rubber Co., *Akron, Ohio.*

STEVENS, HERBERT C. M., consulting engineer, Olds Motor Works, *Lansing, Mich.*

STRICKLAND, HERBERT, mechanical engineer, Ford Motor Co. of Canada, Ltd., *Ford, Ont., Canada.*

TAYLOR, EARL A., works manager, Yellow Sleeve Valve Engine Works, *East Moline, Ill.*

TAYLOR, THEODORE, superintendent of repairs, Standard Oil Co. of New York, *New York City.*

THOMS, WILLIAM F., president, Indiana Lamp Corporation, *Connersville, Ind.*

TRENT, HARRY C., secretary, Colt-Stewart Co., *New York City.*

VOSS, ADOLPH F., experimental engineer, Buda Co., *Harvey, Ill.*

WACKER, FREDERICK C., president, Automotive Maintenance Machinery Co., *Chicago.*

WALKER, EDWIN M., president, Schenectady Railway Co., *Schenectady, N. Y.*

WILLOUGHBY, FRANCIS D., president, Willoughby Co., *Utica, N. Y.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Sept. 10 and Oct. 10, 1925. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

BATSTONE, CHARLES E. (A) road engineer, International Harvester Co. of America, Boston, (mail) 108 Washington Avenue, *Waltham, Mass.*

BROTZ, ANTON F., SR. (M) research engineer, Kohler Co., *Kohler, Wis.*, (mail) 116 Crafton Court.

BURGER, F. A. (A) Sierra Garage, *Colfax, Cal.*

GIFFORD, CLAYTON E. (M) engineer, Huber Mfg. Co., *Marion, Ohio*, (mail) 298 South Grand Avenue.

GREENWOOD, R. C. (M) mechanical engineer, Philbrin Corporation, *Kennett Square, Pa.*

JOHNSON, ROY W. (M) engineer, Paraflector Co., *Kenosha, Wis.*, (mail) 582 West Street.

KILROE, HARRY B. (A) manufacturing engineer, Briggs & Stratton, Inc., *Milwaukee*, (mail) 1530 Grand Avenue.

MYERS, D. F. (M) engineer, Service Motors, Inc., *Wabash, Ind.*, (mail) R. R. No. 4.

PARSONS, CARL B. (M) president, Parsons Mfg. Co., Detroit, (mail) 947 Berkshire Road, *Grosse Pointe Park, Detroit.*

SAUERBREY, PAUL C. (A) general superintendent, Muncie products division of General Motors Corporation, *Muncie, Ind.*, (mail) 163 Burlington Road.

STEARNS, H. E., JR. (A) engineer, Engine & Carburetor Co., *Baltimore, Md.*, (mail) 1222 North Charles Street.

TATTERSFIELD, ERNEST E. (A) field engineer, Dave P. Kingsley Co., 1152 South Grand Avenue, *Los Angeles.*

WATSON, HARVEY L. (M) engineering manager, automotive division, Hyatt Roller Bearing Co., General Motors Building, *Detroit.*

WHITBECK, J. E. (M) superintendent air mail, Air Mail Service, Post Office Department, *Cleveland.*